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SALEM:
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J. W. Foster, *President.*

O. N. Rood, *Vice-President.*

Joseph Lovering, *Permanent Secretary.*

O. C. Marsh, *General Secretary.*

Dr. A. L. Elwyn, *Treasurer.*

Standing Committee.

EX-OFFICIO.

J. W. Foster,
O. N. Rood,
Joseph Lovering,
O. C. Marsh,
B. A. Gould,
Charles Whittlesey,
A. P. Rockwell,
A. L. Elwyn.

AS CHAIRMEN OF THE SECTIONAL COMMITTEES.

Joseph Henry,
Louis Agassiz.

FROM THE ASSOCIATION AT LARGE.

Alexis Caswell,
T. S. Hunt,
W. C. Kerr,
J. S. Newberry,
Benjamin Peirce,
John Torrey.

Local Committee.

Henry Wheatland, *Chairman.*
F. W. Putnam, *Secretary.*
William Sutton, *Treasurer.*

E. S. Atwood,
E. E. Austin,
J. H. Batchelder,
J. Bertram,
E. Bicknell,
R. Brookhouse,
William Cogswell,
C. Cooke,
B. Cox,
A. Crosby,
A. W. Dodge,
W. C. Endicott,
A. C. Goodell, Jr.,
L. B. Harrington,
N. A. Horton,
A Huntington,
A. Hyatt,
A. H. Johnson,
J. Kimball,
H. F. King,
J. C. Lee,
G. B. Loring,
E. S. Morse,
C. S. Osgood,
J. C. Osgood,
A. S. Packard, Jr.,
C. W. Palfray,
C. R. Palmer,
S. E. Peabody,
G. Perkins,
G. A. Perkins,
W. P. Phillips,
G. D. Phippen,
C. H. Price,
R. S. Rantoul,
J. Robinson,
C. A. Ropes,
G. P. Russell,
B. H. Silsbee,
A. A. Smith,
E. Sutton,
J. C. Towne,
W. P. Upham,
R. P. Waters,
B. Webb, Jr.,
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H. L. Williams,
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PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

EIGHTEENTH MEETING,

HELD AT

SALEM, MASSACHUSETTS,

AUGUST, 1869.

CAMBRIDGE:
PUBLISHED BY JOSEPH LOVERING.
1870.

3. *Committee to act with the Standing Committee in nomination of officers for the Troy Meeting.*

Section A.*

E. W. Blake,
E. B. Elliott,
W. A. Norton,
C. A. Young,

Section B.

W. P. Blake,
C. F. Hartt,
W. C. Kerr,
R. P. Stevens.

4. *Committee to select the time and place of the next meeting.*

J. S. Newberry,
T. S. Hunt,
Joseph Henry,
L. H. Morgan,
John Torrey.

5. *Committee for assisting the Local Committee in making arrangements with the Railroads for transporting the members to and from the next meeting.*

J. H. Devereux,
Samuel M. Felton,
J. W. Foster,
M. D. Hanover,
G. B. Loring,
L. H. Morgan,
William B. Ogden,
James D. Warner.

*E. B. Elliott and C. A. Young were chosen to fill the vacancies caused by the absence of G. W. Hough and E. N. Horsford, who were originally chosen.

OFFICERS OF THE TROY MEETING.

William Chauvenet, *President.*
T. S. Hunt, *Vice-President.*
Joseph Lovering, *Permanent Secretary.*
C. F. Hartt, *General Secretary.*
A. L. Elwyn, *Treasurer.*

Standing Committee.

William Chauvenet,
T. S. Hunt,
Joseph Lovering,
C. F. Hartt,
J. W. Foster,
O. N. Rood,
O. C. Marsh,
A. L. Elwyn.

Local Committee.

John A. Griswold, *Chairman.*
George C. Burdett, *First Vice-Chairman.*
P. V. Hagner, *Second Vice-Chairman.*
Benj. H. Hall, *General Secretary.*
H. B. Nason, *Corresponding Secretary.*
Adam R. Smith, *Treasurer.*

E. W. Arms,
Miles Beach,
E. W. Boughton,
Irving Browne,
H. Burden,
J. A. Burden,
E. Corning, Jr.,
D. Cowee,
G. H. Cramer,
C. Drowne,
C. E. Dutton,
William Fenton,
J. L. Flagg,
James Forsyth,
James Hall,
W. H. Hart,
J. C. Heartt,
J. S. Heartt,
A. L. Holley,
C. R. Ingalls,
A. G. Johnson,
G. B. Kellogg,
Justin Kellogg,
William Kemp,
J. S. Knowlson,
J. H. C. Lajoie,
F. B. Leonard,
H. C. Lockwood,
J. Romeyn,
H. Rousseau,
W. P. Seymour,
W. A. Shepard,
N. B. Squires,
G. H. Starbuck,
F. S. Thayer,
W. A. Thompson,
James Thorn,
Dudley Tibbits,
C. W. Tillinghast,
M. I. Townsend.
J. I. Tucker,
D. T. Vail,

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EDITED BY

JOSEPH LOVERING,

Permanent Secretary.

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O. N. Rood, *Vice-President.*

Joseph Lovering, *Permanent Secretary.*

O. C. Marsh, *General Secretary.*

Dr. A. L. Elwyn, *Treasurer.*

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Joseph Lovering,
O. C. Marsh,
B. A. Gould,
Charles Whittlesey,
A. P. Rockwell,
A. L. Elwyn.

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Joseph Henry,
Louis Agassiz.

FROM THE ASSOCIATION AT LARGE.

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T. S. Hunt,
W. C. Kerr,
J. S. Newberry,
Benjamin Peirce,
John Torrey.

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F. W. PUTNAM, *Secretary.*
WILLIAM SUTTON, *Treasurer.*

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E. E. AUSTIN,
J. H. BATCHELDER,
J. BERTRAM,
E. BICKNELL,
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B. A. WEST,
S. G. WHEATLAND,
H. L. WILLIAMS,
E. B. WILLSON.

RULE 10. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declare such to be his wish before presenting it to the Association.

RULE 11. Copies of all communications, made either to the General Association or to the Sections, must be furnished by the authors; otherwise only the titles, or abstracts, shall appear in the published proceedings.

RULE 12. All papers, either at the general or in the sectional meetings, shall be read, as far as practicable, in the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the proper Sectional Committee.

RULE 13. If any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

RULE 14. No exchanges shall be made between members without authority of the respective Sectional Committees.

GENERAL AND EVENING MEETINGS.

RULE 15. The Standing Committee shall appoint any general meeting which the objects and interests of the Association may call for, and the evenings shall, as a rule, be reserved for general meetings of the Association.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Sections.

It shall be a part of the business of these general meetings to receive the Address of the President of the last meeting; to hear such reports on scientific subjects as, from their general importance and interests, the Standing Committee shall select; also, to receive from the Chairman of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

RULE 16. The Association shall be called to order by the President of the preceding meeting; and this officer having resigned the chair to the President elect, the General Secretary shall then report the number of papers relating to each department which have been registered, and the Association consider the most eligible distribution into Sections, when it shall proceed to the election of the additional members of the Standing Committee in the manner before described; the meeting shall then adjourn, and the Standing Committee, having divided the Association into sections as directed, shall allot to each its place of meeting for the Session. The Sections shall then organize by electing their officers and their representatives in the Nominating Committee, and shall proceed to business.

PERMANENT SECRETARY.

RULE 17. It shall be the duty of the Permanent Secretary to notify members who are in arrears, to provide the necessary stationery and suitable books for the list of members and titles of papers, minutes of the general and sectional meetings, and for other purposes indicated in the rules, and to execute such other duties as may be directed by the Standing Committee or by the Association.

The Permanent Secretary shall make a report annually to the Standing Committee, at its first meeting, to be laid before the Association, of the business of which he has had charge since its last meeting.

All members are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

Whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the proceedings of the Association, he is authorized to commit the same to the author, or to the proper subcommittee of the Standing Committee for correction.

LOCAL COMMITTEE.

RULE 18. The Local Committee shall be appointed from among members residing at, or near, the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements and the necessary announcements for the meeting.

The Secretary of the Local Committee shall issue a circular in regard to the time and place of meetings, and other particulars, at least one month before each meeting.

SUBSCRIPTIONS.

RULE 19. The amount of the subscription, at each meeting, of each member of the Association, shall be two dollars, and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. These subscriptions shall be received by the Permanent Secretary, who shall pay them over, after the meeting, to the Treasurer.

The admission fee of new members shall be five dollars, in addition to the annual subscription: and no person shall be considered a member of the Association until this admission fee and the subscription for the meeting at which he is elected have been paid.

RULE 20. The names of all persons two years in arrears for annual dues shall be erased from the list of members; provided that two notices of indebtedness, at an interval of at least three months, shall have been previously given.

ACCOUNTS.

RULE 21. The accounts of the Association shall be audited, annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 22. No article of this Constitution shall be altered, or amended, or set aside, without the concurrence of three-fourths of the members present, and unless notice of the proposed change shall have been given at the preceding annual meeting.*

---

* See page xxii.

RESOLUTIONS

OF A PERMANENT AND PROSPECTIVE CHARACTER, ADOPTED AUGUST 19, 1857.

1. No appointment may be made in behalf of the Association, and no invitation given or accepted, except by vote of the Association or its Standing Committee.

2. The General Secretary shall transmit to the Permanent Secretary for the files, within two weeks after the adjournment of every meeting, a record of the proceedings of the Association and the votes of the Standing Committee. He shall also, daily, during the meetings, provide the Chairman of the two Sectional Committees with lists of the papers assigned to their Sections by the Standing Committee.

3. All printing for the Association shall be superintended by the Permanent Secretary, who is authorized to employ a clerk for that especial purpose.

4. The Permanent Secretary is authorized to put the proceedings of the meeting to press one month after the adjournment of the Association. Papers which have not been received at that time may be published only by title. No notice of articles not approved shall be taken in the published proceedings.

5. The Permanent Chairman of the Sections are to be considered their organs of communication with the Standing Committee.

6. It shall be the duty of the Secretaries of the two Sections to receive copies of the papers read in their Sections, all subsections included, and to furnish them to the Permanent Secretary at the close of the meeting.

7. The Sectional Committees shall meet not later than 9 A.M. daily, during the meetings of the Association, to arrange the programmes of their respective sections, including all sub-

sections, for the following day. No paper shall be placed upon these programmes which shall not have been assigned to the Section by the Standing Committee. The programmes are to be furnished to the Permanent Secretary not later than 11 A.M.

8. During the meetings of the Association, the Standing Committee shall meet daily, Sundays excepted, at 9 A.M., and the Sections be called to order at 10 A.M., unless otherwise ordered. The Standing Committee shall also meet on the evening preceding the first assembling of the Association at each annual meeting, to arrange for the business of the first day; and on this occasion three shall form a quorum.

9. Associate members may be admitted for one, two, or three years as they shall choose at the time of admission,—to be elected in the same way as permanent members, and to pay the same dues. They shall have all the social and scientific privileges of members, without taking part in the business.

10. No member may take part in the organization and business arrangement of both the Sections.

It has been proposed to amend Rule 5 of the Constitution, by inserting before the last section the following: "When not otherwise ordered, the sub-sections shall be as follows:

SECTION A.—1. Mathematics and Astronomy; 2. Physics and Chemistry; 3. Microscopy.

SECTION B.—1. Zoology and Botany; 2. Geology and Palæontology; 3. Ethnology and Archæology."

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

A.

Abbe, Cleveland, Cincinnati, Ohio (16).
*Adams, C. B., Amherst, Massachusetts (1).
Adelberg, Justus, New York, New York (15).
Agassiz, Louis, Cambridge, Massachusetts (1).
Aiken, W. E. A., Baltimore, Maryland (12).
Albert, Augustus J., Baltimore, Maryland (12).
Allen, Zachariah, Providence, Rhode Island (1).
Alvord, Benjamin, Omaha, Nebraska (17).
*Ames, M. P., Springfield, Massachusetts (1).
Andrews, Ebenezer, Chicago, Illinois (17).
Andrews, Edmund, Chicago, Illinois (17).
Andrews, E. B., Marietta, Ohio (7).
Andrews, Joseph H., Chicago, Illinois (17).
Angell, James B., Burlington, Vermont (16).
*Appleton, Nathan, Boston, Massachusetts (1).
Atwater, Elizabeth E., Chicago, Illinois (17).
Atwater, Samuel T., Chicago, Illinois (17).

B.

Babcock, Henry H., Chicago, Illinois (17).
*Bache, Alexander D., Washington, District of Columbia (1).
Bacon, John, Jr., Boston, Massachusetts (1).
*Bailey, J. W., West Point, New York (1).
Baird, Lyman, Chicago, Illinois (17).
Baird, S. F., Washington, District of Columbia (1).

NOTE.—Names of deceased members are marked with an asterisk [*]. The figure at the end of each name refers to the meeting at which the elections took place.

Bannister, Henry M., Evanston, Illinois (17).
Bardwell, F. W., Jacksonville, Florida (13).
Barker, G. F., New Haven, Connecticut (13).
Barnard, F. A. P., New York, New York (7).
Barnard, J. G., Washington, District of Columbia (14).
Basnett, Thomas, Ottawa, Illinois (8).
Batchelder, J. M., Cambridge, Massachusetts (8).
Beaty, John F., Chicago, Illinois (17).
*Beck, C. F., Philadelphia, Pennsylvania (1).
*Beck, Lewis C., New Brunswick, New Jersey (1).
*Beck, T. Romeyn, Albany, New York (1).
Beebe, G. D., Chicago, Illinois (17).
*Bell, Samuel N., Manchester, New Hampshire (7).
Benedict, G. W., Burlington, Vermont (16).
Bickmore, Albert S., New York, New York (17).
Bigelow, George H., Burlington, Vermont (16).
Bill, Charles, Chicago, Illinois (17).
*Binney, Amos, Boston, Massachusetts (1).
*Binney, John, Boston, Massachusetts (3).
Blake, Eli W., Ithaca, New York (15).
Blake, Eli W., New Haven, Connecticut (1).
Blake, W. P., San Francisco, California (2).
*Blanding, William, Rhode Island (1).
Blaney, J. Van Zandt, Chicago, Illinois (12).
Blatchford, Eliphalet W., Chicago, Illinois (17).
Bolles, E. C., Brooklyn, New York (17).
Bolton, H. C., New York, New York (17).
*Bomford, George, Washington, District of Columbia (1).
Bouvé, Thomas T., Boston, Massachusetts (1).
Bowditch, Henry I., Boston, Massachusetts (2).
Bowen, Chauncey W., Chicago, Illinois (17).
Bradley, Francis, Chicago, Illinois (17).
Bradley, L., Jersey City, New Jersey (15).
Brevoort, J. Carson, Brooklyn, New York (1).
Briggs, A. D., Springfield, Massachusetts (13).
Briggs, S. A., Chicago, Illinois (17).
Bross, William, Chicago, Illinois (7).
Brown, Robert, Jr., Cincinnati, Ohio (11).
Brush, George J., New Haven, Connecticut (11).
Bryan, Thomas B., Chicago, Illinois (17).
Buchanan, Robert, Cincinnati, Ohio (2).
*Burnap, G. W., Baltimore, Maryland (12).
*Burnett, Waldo I., Boston, Massachusetts (1).
Burroughs, J. C., Chicago, Illinois (17).
Bushee, James, Worcester, Massachusetts (9).
Butler, Thomas B., Norwalk, Connecticut (10).

C.

Calhoun, John B., Chicago, Illinois (17).
Canby, William M., Wilmington, Delaware (17).
*Carpenter, Thornton, Camden, South Carolina (7).
*Carpenter, William M., New Orleans, Louisiana (1).
Carter, Asher, Chicago, Illinois (17)
Case, Leonard, Cleveland, Ohio (15).
Case, L. B., Richmond, Indiana (17).
*Case, William, Cleveland, Ohio (6).
Cassels, J. L., Cleveland, Ohio (7).
Caswell, Alexis, Providence, Rhode Island (2).
Cattell, William C., Easton, Pennsylvania (15).
Chadbourn, P. A., Madison, Wisconsin (10).
Chanute, O., Kansas City, Kansas (17).
Chapman, F. M., Chicago, Illinois (17).
*Chapman, N., Philadelphia, Pennsylvania (1).
Chase, George I., Providence, Rhode Island (1).
*Chase, S., Dartmouth, New Hampshire (2).
Chauvenet, William, St. Louis, Missouri (1).
Chesbrough, E. S., Chicago, Illinois (2).
Chittenden, L. E., New York, New York (14).
*Clapp, Asahel, New Albany, Indiana (1).
Clark, John E., Yellow Springs, Ohio (17).
*Clark, Joseph, Cincinnati, Ohio (5).
*Cleveland, A. B., Cambridge, Massachusetts (2).
Cochran, D. H., Brooklyn, New York (15).
Coffin, James H., Easton, Pennsylvania (1).
Coffin, John H. C., Washington, District of Columbia (1).
Colbert, E., Chicago, Illinois (17).
*Cole, Thomas, Salem, Massachusetts (1).
*Coleman, Henry, Boston, Massachusetts (1).
Conant, Marshall, Northampton, Massachusetts (7).
Conkling, Frederick A., New York, New York (11).
Cope, Edward D., Philadelphia, Pennsylvania (17).
Copes, Joseph S., New Orleans, Louisiana (11).
Corning, Erastus, Albany, New York (6).
Craig, B. F., Washington, District of Columbia (15).
Cramp, J. M., Acadia College, Nova Scotia (11).
Crosby, Alpheus, Salem, Massachusetts (10).
Culver, Howard Z., Chicago, Illinois (17).
Cummings, Joseph, Middletown, Connecticut (13).
Cutting, Hiram A., Lunenburg, Vermont (17).

D.

Dalrymple, E. A., Baltimore, Maryland (11).

Dana, James D., New Haven, Connecticut (1).
Danforth, Edward, Troy, New York (11).
Davis, James, Boston, Massachusetts (1).
Davis, N. S., Chicago, Illinois (17).
Dawson, J. W., Montreal, Canada (10).
*Dean, Amos, Albany, New York (6).
Dean, George W., Fall River, Massachusetts (15).
*Dearborn, George H. A. S., Roxbury, Massachusetts (1).
*Dekay, James E., New York, New York (1).
Delano, B. L., Boston, Massachusetts (16).
Delano, Joseph C., New Bedford, Massachusetts (5).
*Dewey, Chester, Rochester, New York (1).
Dexter, G. M., Boston, Massachusetts (11).
Dinwiddle, Robert, New York, New York (1).
Dixwell, Eps S., Cambridge, Massachusetts (1).
Doggett, Kate N., Chicago, Illinois (17).
Doggett, William E., Chicago, Illinois (17).
Dorr, E. P., Buffalo, New York (15).
Downes, John, Washington, District of Columbia (10).
Drowne, Charles, Troy, New York (6).
*Ducatel, J. T., Baltimore, Maryland (1).
*Dumont, A. H., Newport, Rhode Island (14).
*Duncan, Lucius C., New Orleans, Louisiana (10).
Duncan, T. C., Chicago, Illinois (17).
*Dunn, R. P., Providence, Rhode Island (14).
Dyer, Elisha, Providence, Rhode Island (9).

E.

Easton, Norman, Fall River, Massachusetts (14).
Eaton, Daniel C., New Haven, Connecticut (13).
Eaton, James H., Amherst, Massachusetts (17).
Edwards, J. B., Montreal, Canada (17).
Eimbeck, William, St. Louis, Missouri (17).
Eliot, Charles W., Boston, Massachusetts (14).
Elliott, Ezekiel B., Washington, District of Columbia (10).
Elwyn, Alfred L., Philadelphia, Pennsylvania (1.)
Emerson, George B., Boston, Massachusetts (1).
Englemann, George, St. Louis, Missouri (1).
Engstrom, A. B., Burlington, New Jersey (1).
Eustis, Henry L., Cambridge, Massachusetts (2).
*Everett, Edward, Boston, Massachusetts (2).

F.

Fairbanks, Henry, Hanover, New Hampshire (14).
Farmer, Moses G., Salem, Massachusetts (9).
Farnham, Thomas, Buffalo, New York (15).

Farrar, Henry W., Chicago, Illinois (17).
Ferrell, William, Nashville, Tennessee (11).
Ferris, Isaac, New York, New York (6).
Feuchtwanger, Louis, New York, New York (11).
Fillmore, Millard, Buffalo, New York (7).
Fisher, Davenport, Milwaukie, Wisconsin (17).
Fisher, Mark, Trenton, New Jersey (10).
*Fitch, Alexander, Hartford, Connecticut (1).
Fitch, Edward H., Ashtabula, Ohio (11).
Fitch, O. H., Ashtabula, Ohio (7).
*Forbush, E. B., Buffalo, New York (15).
Foster, Henry, Clifton, New York (17).
Foster, John, Schenectady, New York (17).
Foster, J. W., Chicago, Illinois (1).
*Fox, Charles, Grosse Isle, Michigan (7).
Frothingham, Frederick, Buffalo, New York (11).

G.

*Gay, Martin, Boston, Massachusetts (1).
Gibbon, J. H., Charlotte, North Carolina (3).
Gibbs, Wolcott, Cambridge, Massachusetts (1).
Gill, Theodore, Washington, District of Columbia (17).
*Gillespie, W. M., Schenectady, New York (10).
Gilman, Daniel C., New Haven, Connecticut (10).
*Gilmor, Robert, Baltimore, Maryland (1).
Glynn, James, Geneva, New York (1).
Gold, Theodore S., West Cornwall, Connecticut (4).
*Gould, Augustus A., Boston, Massachusetts (11).
*Gould, B. A., Boston, Massachusetts (2).
Gould, B. A., Cambridge, Massachusetts (2).
*Graham, James D., Washington, District of Columbia (1).
Gray, Asa, Cambridge, Massachusetts (1).
*Gray, James H., Springfield, Massachusetts (6).
Greeley, Samuel S., Chicago, Illinois (17).
Green, Traill, Easton, Pennsylvania (1).
*Greene, Benjamin D., Boston, Massachusetts (1).
Greene, Dascom, Troy, New York (17).
Greene, Francis C., Easthampton, Massachusetts (11).
*Griffith, Robert E., Philadelphia, Pennsylvania (1).
'Grimes, J. S., New York, New York (17).
Grinnan, A. G., Orange Court House, Virginia (7).
Grover, Z., Chicago, Illinois (17).
Guyot, Arnold, Princeton, New Jersey (1).

H.

*Hackley, Charles W., New York, New York (4).

Hadley, George, Buffalo, New York (6).
Hager, Hermann A., Cambridge, Massachusetts (17).
Haldeman, S. S., Columbia, Pennsylvania (1).
Hale, Edwin M., Chicago, Illinois (17).
* Hale, Enoch, Boston, Massachusetts (1).
Hall, James, Albany, New York (1).
Hall, N. K., Buffalo, New York (7).
Hamlin, A. C., Bangor, Maine (10).
Hance, Ebenezer, Morrisville, Pennsylvania (7).
Hanover, M. D., Cincinnati, Ohio (13).
* Hare, Robert, Philadelphia, Pennsylvania (11).
* Harlan, Joseph G., Haverford, Pennsylvania (8).
* Harlan, Richard, Philadelphia, Pennsylvania (1).
* Harris, Thaddeus W., Cambridge, Massachusetts (1).
Harrison, B. F., Wallingford, Connecticut (11).
* Hart, Simeon, Farmington, Connecticut (1).
Hartshorne, Henry, Philadelphia, Pennsylvania (12).
Haven, Joseph, Chicago, Illinois (17).
Hawkins, B. W., New York, New York (17).
* Hayden, H. H., Baltimore, Maryland (1).
Hayes, George E., Buffalo, New York (15).
* Hayward, James, Boston, Massachusetts (1).
Henry, Joseph, Washington, District of Columbia (1).
Herzer, W., Columbus, Ohio (15).
Hickcox, S. V. R., Chicago, Illinois (17).
Hickok, W. C., Burlington, Vermont (16).
Hilgard, Eugene W., Oxford, Mississippi (11).
Hilgard, Julius E., Washington, District of Columbia (4).
Hilgard, Theodore C., St. Louis, Missouri (17).
Hill, S. W., Hancock, Lake Superior (6).
Hill, Thomas, Waltham, Massachusetts (8).
Hinrichs, Gustavus, Iowa City, Iowa (17).
Hitt, Isaac R., Chicago, Illinois (17).
Hitchcock, Charles H., Hanover, New Hampshire (11).
* Hitchcock, Edward, Amherst, Massachusetts (1).
Hitchcock, Edward, Amherst, Massachusetts (4).
Hoadley, E. S., Springfield, Massachusetts (13).
Holbrook, J. E., Charleston, South Carolina (1).
Holmes, E. L., Chicago, Illinois (17).
Holmes, Henry A., Albany, New York (11).
Horsford, E. N., Cambridge, Massachusetts (1).
* Horton, William, Craigville, New York (1).
Hough, Franklin B., Lowville, New York (4).
Hough, G. W., Albany, New York (15).
* Houghton, Douglas, Detroit, Michigan (1).
Howell, Robert, Nichols, New York (6).

Hoy, Philo R., Racine, Wisconsin (17).
Hubbard, Gurdon S., Chicago, Illinois (17).
Hubbard, Oliver P., Hanover, New Hampshire (1).
Hubbard, Sara A., Kalamazoo, Michigan (17).
*Hubbert, James, Richmond, Province of Quebec (16).
Hungerford, Edward, Burlington, Vermont (10).
Hunt, Charles S., New York, New York (17).
*Hunt, E. B., Washington, District of Columbia (2).
*Hunt, Freeman, New York, New York (11).
Hunt, George, Providence, Rhode Island (9).
Hunt, T. Sterry, Montreal, Canada (1).
Hyatt, James, Bangall, New York (10).

I.

*Ives, Thomas P., Providence, Rhode Island (10).

J.

Jenks, J. W. P., Middleboro', Massachusetts (2).
Jillson, B. C., Nashville, Tennessee (14).
*Johnson, W. R., Washington, District of Columbia (1).
Johnston, John, Middletown, Connecticut (1).
*Jones, Catesby A. R., Washington, District of Columbia (8).
Joy, C. A., New York, New York (8).
Judd, Orange, New York, New York (4).

K.

Kedzie, J. H., Chicago, Illinois (17).
Keely, G. W., Waterville, Maine (1).
Keep, N. C., Boston, Massachusetts (13).
Kerr, W. C., Raleigh, North Carolina (10).
Kimball, J. P., New York, New York (15).
King, Mary B. A., Rochester, New York (15).
Kirkpatrick, James A., Philadelphia, Pennsylvania (7).
Kirkwood, Daniel, Canonsburg, Pennsylvania (7).
Kite, Thomas, Cincinnati, Ohio (5).
Klippart, John H., Columbus, Ohio (17).
Knickerbocker, Charles, Chicago, Illinois (17).

L.

Lapham, Increase A., Milwaukee, Wisconsin (3).
*Lasel, Edward, Williamstown, Massachusetts (1).
Lattimore, S. A., Rochester, New York (15).
Lawrence, George N., New York, New York (7).
Lea, Isaac, Philadelphia, Pennsylvania (1).
Leakin, George A., Baltimore, Maryland (17).
LeConte, John L., Philadelphia, Pennsylvania (1).

*Lederer, Baron von, Washington, District of Columbia (1).
Lesley, Joseph, Jr., Philadelphia, Pennsylvania (8).
Lesley, J. P., Philadelphia, Pennsylvania (2).
Letchworth, William P., Portage, New York (15).
*Lieber, Oscar M., Columbia, South Carolina (8).
*Lincklaen, Ledyard, Cazenovia, New York (1)
Lincoln, Robert T., Chicago, Illinois (17).
Lindsley, J. B., Nashville, Tennessee (1).
*Linsley, James H., Stafford, Connecticut (1).
Little, George, Oxford, Mississippi (15).
Locke, Luther F., Nashua, New Hampshire (7).
Logan, William E., Montreal, Canada (1).
Lombard, Benjamin, Chicago, Illinois (17).
Loomis, Elias, New Haven, Connecticut (1).
Loosey, Charles F., New York, New York (12).
*Lothrop, Joshua R., Buffalo, New York (15).
Lovering, Joseph, Cambridge, Massachusetts (2).
Lunn, William, Montreal, Canada (11).
Lupton, N. T., Greensboro, Alabama (17).
Lyman, B. S., Philadelphia, Pennsylvania (15).
Lyman, Chester S., New Haven, Connecticut (14).
Lyman, Henry M., Chicago, Illinois (17).
Lynch, P. N., Charleston, South Carolina (2).

M.

*M'Conihe, Isaac, Troy, New York (4).
McCagg, Ezra B., Chicago, Illinois (17).
McMurtrie, Horace, Boston, Massachusetts (17).
McRae, John, Camden, South Carolina (3).
Marcy, Oliver, Evanston, Illinois (10).
*Marsh, Dexter, Greenfield, Massachusetts (1).
Marsh, H. H., Chicago, Illinois (17).
Marsh, O. C., New Haven, Connecticut (15).
Marshall, Charles D., Buffalo, New York (15).
Marshall, Orasmus H., Buffalo, New York (15).
*Mather, William W., Columbus, Ohio (1).
Mauran, J., Providence, Rhode Island (2).
Mayhew, D. P., Ypsilanti, Michigan (13).
Maynard, Alleyne, Cleveland, Ohio (7).
Meade, George G., Philadelphia, Pennsylvania (15).
Means, A., Oxford, Georgia (5).
Meehan, Thomas, Germantown, Pennsylvania (17).
Meek, F. B., Washington, District of Columbia (6).
Meigs, James A., Philadelphia, Pennsylvania (12)
Miles, Henry H., Quebec, Canada East (11).
Miller, Samuel, New Haven, Connecticut (14).

Minifie, William, Baltimore, Maryland (12).
Mitchell, Maria, Poughkeepsie, New York (4).
Mitchell, William H., Florence, Alabama (17).
Morgan, Lewis H., Rochester, New York (10).
Morris, John G., Baltimore, Maryland (12).
*Morton, S. G., Philadelphia, Pennsylvania (1).
Murray, David, New Brunswick, New Jersey (11).

N.

Nason, Henry B., Troy, New York (13).
Nelson, Cleland K., Annapolis, Maryland (12).
Newberry, J. S., New York, New York (5).
Newcomb, Simon, Washington, District of Columbia (13).
*Newton, E. H., Cambridge, New York (1).
Newton, Hubert A., New Haven, Connecticut (6).
Nichols, Charles A., Providence, Rhode Island (17).
*Nicollett, J. N., Washington, District of Columbia (1).
Niles, W. H., Cambridge, Massachusetts (16).
*Norton, J. P., New Haven, Connecticut (1).
Norton, W. A., New Haven, Connecticut (6).

O.

*Oakes, William, Ipswich, Massachusetts (1).
Ogden, Mahlon D., Chicago, Illinois (17).
Ogden, W. B., Chicago, Illinois (17).
Oliver, James Edward, New York, New York (7).
*Olmsted, Alexander F., New Haven, Connecticut (4).
*Olmsted, Denison, New Haven, Connecticut (1).
*Olmsted, Denison, Jr., New Haven, Connecticut (1).
Ordway, John M., Jamaica Plain, Massachusetts (9).
Osten Sacken, Baron R. von, New York, New York (10).

P.

Packard, A. S., Jr., Salem, Massachusetts (16).
Page, Peter, Chicago, Illinois (17).
Paine, Cyrus F., Rochester, New York (12).
Painter, Minshall, Lima, Pennsylvania (7).
*Parkman, Samuel, Boston, Massachusetts (1).
Parmelee, Dubois D., New York, New York (15).
Parry, Charles C., Washington, District of Columbia (6).
Peabody, S. H., Chicago, Illinois (17).
Peck, Edward W., Burlington, Vermont (16).
Peirce, Benjamin, Cambridge, Massachusetts (1).
Perkins, George H., Providence, Rhode Island (17).
Perkins, George R., Utica, New York (1).
Perkins, Maurice, Schenectady, New York (15).
Perry, John B., Cambridge, Massachusetts (16).

*Perry, M. C., New York, New York (10).
Phelps, Almira L., Baltimore, Maryland (13).
Phelps, Charles E., Baltimore, Maryland (13).
*Plumb, Ovid, Salisbury, Connecticut (9).
*Porter, John A., New Haven, Connecticut (14).
Pourtales, L. F., Washington, District of Columbia (1).
Powell, Edwin, Chicago, Illinois (17).
Prescott, William, Concord, New Hampshire (1).
Pruyn, J. V. L., Albany, New York (1).
*Pugh, Evan, Centre Co., Pennsylvania (14).
Pumpelly, Raphael, Cambridge, Massachusetts (17).
Putnam, F. W., Salem, Massachusetts (10).

Q.

Quincy, Edmund, Jr., Boston, Massachusetts (11).

R.

Rauch, J. H., Chicago, Illinois (11).
Raymond, R. W., New York, New York (15).
Read, Daniel, Columbia, Missouri (11).
Redfield, John H., Philadelphia, Pennsylvania (1).
*Redfield, William C., New York, New York (1).
Riley, Charles V., St. Louis, Missouri (17).
Ritchie, E. S., Boston, Massachusetts (10).
Robertson, Thomas D., Rockford, Illinois (10).
Rochester, Thomas F., Buffalo, New York (15).
Rockwell, Alfred P., New Haven, Connecticut (10).
Rockwell, John, La Salle, Illinois (11).
*Rockwell, John A., Norwich, Connecticut (10).
Rockwell, Joseph P., New Haven, Connecticut (17).
Rodman, William M., Providence, Rhode Island (9).
Rogers, Fairman, Philadelphia, Pennsylvania (11).
*Rogers, James B., Philadelphia, Pennsylvania (1).
Rogers, W. A., Alfred Centre, New York (15).
Rogers, W. B., Boston, Massachusetts (1).
Rood, O. N., New York, New York (14).
Roosevelt, Clinton, New York, New York (11).
Root, Edward W., Clinton, New York (17).
Rumsey, Bronson C., Buffalo, New York (15).
Rumsey, George T., Chicago, Illinois (17).
Runkle, J. D., Boston, Massachusetts (2).
Rutherford, Louis M., New York, New York (13).
Ryerson, Joseph T.. Chicago, Illinois (17).

S.

Safford, J. M., Nashville, Tennessee (6).
Safford, Truman, H., Chicago, Illinois (13).

Sanborn, Francis G., Boston, Massachusetts (13).
Sargent, Rufus, Auburn, New York (10).
Scammon, J. Young, Chicago, Illinois (17).
Schanck, J. Stillwell, Princeton, New Jersey (4).
Schott, Charles A., Washington, District of Columbia (8).
Scudder, Samuel H., Cambridge, Massachusetts (13).
Seward, William H., Auburn, New York (1).
Sheafer, P. W., Pottsville, Pennsylvania (4).
Sheldon, Edwin H., Chicago, Illinois (17).
Shepard, C. U., Amherst, Massachusetts (4).
Sherwood, Albert, Buffalo, New York (15).
Sias, Solomon, Charlotteville, New York (10).
Sill, Elisha N., Cuyahoga Falls, Ohio (6).
*Silliman, Benjamin, New Haven, Connecticut (1).
Silliman, Benjamin, New Haven, Connecticut (1).
Smith, A. D., Providence, Rhode Island (14).
Smith, J. L., St. Louis, Missouri (14).
*Smith, J. V., Cincinnati, Ohio (5).
Smith, James Y., Providence, Rhode Island (9).
*Smith, Lyndon A., Newark, New Jersey (9).
Snell, Eben S., Amherst, Massachusetts (2).
*Sparks, Jared, Cambridge, Massachusetts (2).
Spencer, Charles A., Brooklyn, New York (14).
Sprague, Albert A., Chicago, Illinois (17).
Spring, Charles H., Boston, Massachusetts (13).
Stanard, Benjamin A., Cleveland, Ohio (6).
Stearns, Josiah A. ,Boston, Massachusetts (10).
Steiner, Lewis H., Frederick City, Maryland (7).
Stimpson, William, Chicago, Illinois (12).
Stoddard, O. N., Oxford, Ohio (7).
Stone, Samuel, Chicago, Illinois (17).
Storer, D. H., Boston, Massachusetts (1).
Storer, Frank H., Boston, Massachusetts (13).
Sullivant, W. S., Columbus, Ohio (7).
Swasey, Oscar F., Beverly, Massachusetts (17).

T.

*Tallmadge, James, New York, New York (1).
*Taylor, Richard C., Philadelphia, Pennsylvania (1).
Tenney, Samuel, Williamstown, Massachusetts (17).
*Teschemacher, J. E., Boston, Massachusetts (1).
Thompson, Aaron R., New York, New York (1).
Thompson, Harvey M., Chicago, Illinois (17).
*Thompson, Z., Burlington, Vermont (1).
*Thurber, Isaac, Providence, Rhode Island (9).
Tillman, S. D., New York, New York (15).

Tingley, Jeremiah, Meadville, Pennsylvania (15).
Tingley, Joseph, Greencastle, Indiana (14).
Tolles, Robert B., Boston, Massachusetts (15).
Torrey, John, New York, New York (1).
*Totten, J. G., Washington, District of Columbia (1),
Townsend, Franklin, Albany, New York (4).
*Townsend, John K., Philadelphia, Pennsylvania (1).
Townshend, N. S., Avon, Ohio (17).
Tracy, John F., Chicago, Illinois (17).
Trembly, J. B., Toledo, Ohio (17).
*Troost, Gerard, Nashville, Tennessee (1).
True, Nathaniel T., Bethel, Maine (17).
*Tuomey, M., Tuscaloosa, Alabama (1).
Tuttle, Albert H., Cleveland, Ohio (17).
*Tyler, Edward R., New Haven, Connecticut (1).
Tyson, Philip T., Baltimore, Maryland (12).

U.

Upham, J. Baxter, Boston, Massachusetts (14).
Upton, George P., Chicago, Illinois (17).

V.

*Vancleve, John W., Dayton, Ohio (1)
Van der Weyde, P. H., New York, New York (17).
Van Duzee, Mary K., Buffalo, New York (16).
Van Pelt, William, Williamsville, New York (7).
*Vanuxem, Lardner, Bristol, Pennsylvania (1).
Vaux, William S., Philadelphia, Pennsylvania (1).
Verrill, A. E., New Haven, Connecticut (16).
Vose, George L., Paris Hill, Maine (15).
Vought, John H., Buffalo, New York (15).

W.

Waddell, John N., Oxford, Mississippi (17).
*Wadsworth, James S., Genesee, New York (2).
*Wagner, Tobias, Philadelphia, Pennsylvania (9).
Wales, Torrey E., Burlington, Vermont (16).
Wales, William, Fort Lee, New York (15).
Walker, George C., Chicago, Illinois (17).
*Walker, Joseph, Oxford, New York (10).
*Walker, Sears C., Washington, District of Columbia (1).
*Walker, Timothy, Cincinnati, Ohio (4).
Walling, H. F., Easton, Pennsylvania (16).
Ward, Henry A., Rochester, New York (13).
Ward, R. H., Troy, New York (17).
Warren, G. K., Washington, District of Columbia (12).

*Warren, John C., Boston, Massachusetts (1).
Watson, James C., Ann Arbor, Michigan (13).
Watson, William, Cambridge, Massachusetts (12).
*Webster, H. B., Albany, New York (1).
*Webster, J. W., Cambridge, Massachusetts (1).
*Webster, M. H., Albany, New York (1).
Webster, Nathan B., Kenansville, North Carolina (7).
Wenz, J., New Orleans, Louisiana (15).
Wheatland, Henry, Salem, Massachusetts (1).
*Wheatland, Richard H., Salem, Massachusetts (13).
Wheatley, Charles M., Phœnixville, Pennsylvania (1).
Wheeler, T. B., Montreal, Canada (11).
Wheildon, W. W., Charlestown, Massachusetts (13).
Whitney, Asa, Philadelphia, Pennsylvania (1).
Whitney, William D., New Haven, Connecticut (12).
Whittlesey, Charles, Cleveland, Ohio (1).
*Willard, Emma, Troy, New York (15).
Williams, Henry W., Boston, Massachusetts (11).
Williamson, R. S., San Francisco, California (12).
Wilson, Charles L., Chicago, Illinois (17).
Winchell, Alexander, Ann Arbor, Michigan (3).
Winslow, Ferdinand S., Chicago, Illinois (17).
*Woodbury, L., Portsmouth, New Hampshire (1).
Woodworth, John M., Chicago, Illinois, (17).
Worthen, A. H., Springfield, Illinois (5).
Wright, A. W., Williamstown, Massachusetts (14).
Wright, Chauncey, Cambridge, Massachusetts (9).
*Wright, John, Troy, New York (1).
Würtele, Louis C., Acton Vale, Canada East (11).
Wurtz, Henry, New York, New York (10).
Wyman, Jeffries, Cambridge, Massachusetts (I).

Y.

Youmans, E. L., New York, New York (6).
*Young, Ira, Hanover, New Hampshire (7).

This list contains five hundred and twenty names, of which one hundred and nineteen are of deceased members. The names of those who were chosen at Salem, and who have already joined the Association, have not yet been incorporated into the general catalogue of members, but are printed separately on the following pages.

MEMBERS

WHO JOINED AT

THE SALEM MEETING.

A.

Adams, Edwin F., Charlestown, Massachusetts.
Adams, Samuel, Jacksonville, Illinois.
Agassiz, Alexander E. R., Cambridge, Massachusetts.
Allen, J., Alfred Centre, New York.
Allen, Joel A., Cambridge, Massachusetts.
Austin, E. L., Plymouth, Ohio.
Austin, E. P., Cambridge, Massachusetts.

B.

Bachelder, J. H., Salem, Massachusetts.
Bailey, Loring W., Frederickton, New Brunswick.
Bailey, W. W., Providence, Rhode Island.
Barnard, James M., Boston, Massachusetts.
Bethune, Charles J. S., Credit, Canada.
Bicknell, Edwin, Salem, Massachusetts.
Bliss, Porter C., New York, New York.
Boynton, John F., Syracuse, New York.
Briggs, D. H., Norton, Massachusetts.
Bryan, Oliver N., Baltimore, Maryland.
Burbank, L. S., Lowell, Massachusetts.

C.

Chase, Pliny E., Philadelphia, Pennsylvania.
Chase, R. Stuart, Haverhill, Massachusetts.
Clarke, F. W., Ithaca, New York.
Cogswell, William, Salem, Massachusetts.
Cogswell, George, Bradford, Massachusetts.
Cook, George H., New Brunswick, New Jersey.
Cooke, C., Salem, Massachusetts.
Crampton, R. C., Jacksonville, Illinois.
Crosby, Thomas R., Hanover, New Hampshire.

Cummings, John, Woburn, Massachusetts.
Curtis, Josiah, Boston, Massachusetts.

D.

Dall, William H., Washington, District of Columbia.
De Laski, John, Falmouth, Maine.
Devereux, J. H., Cleveland, Ohio.

E.

Edwards, A. M., New York, New York.
Ellenwood, Charles N., San Francisco, California.
Emerton, James H., Salem, Massachusetts.
Endicott, William C., Salem, Massachusetts.

F.

Fellows, R. S., New Haven, Connecticut.
Fenton, William, Troy, New York.
Foucou, Felix, Madison, Wisconsin.
Frothingham, Richard, Charlestown, Massachusetts.

G.

Goessman, C. A., Amherst, Massachusetts.
Goodell, Abner C., Jr., Salem, Massachusetts.
Gregory, J. J. H., Marblehead, Massachusetts.

H.

Hagar, D. B., Salem, Massachusetts.
Hall, L. B., Hanover, New Hampshire.
Hambly, J. B., Portsmouth, Rhode Island.
Hamel, Thomas E., Quebec, Canada.
Hartt, Charles F., Ithaca, New York.
Hoyt, J. W., Madison, Wisconsin.
Humphrey, D., Lawrence, Massachusetts.
Hyatt, Alpheus, Salem, Massachusetts.

J.

Jasper, G. A., Charlestown, Massachusetts.
Johnson, Amos H., Salem, Massachusetts.

L.

Lambert, Thomas R., Charlestown, Massachusetts.
Langley, S. S., Pittsburg, Pennsylvania.
Lawrence, Edward, Charlestown, Massachusetts.
Lockwood, Samuel, Keyport, New Jersey.
Loring, George B., Salem, Massachusetts.
Lyon, Henry, Charlestown, Massachusetts.

M.

Maack, G. A., Cambridge, Massachusetts.
Mack, David, Belmont, Massachusetts.
McNeil, J. A., Grand Rapids, Michigan.
Marden, George H., Charlestown, Massachusetts.
Maynard, George W., Troy, New York.
Monroe, William, Boston, Massachusetts.
Morley, Edward W., Pittsfield, Massachusetts.
Morse, Edward S., Salem, Massachusetts.

N.

Nichols, William R., Boston, Massachusetts.

O.

Orton, James, Poughkeepsie, New York.

P.

Paine, Nathaniel, Worcester, Massachusetts.
Patton, William W., Chicago, Illinois.
Peckham, S. F., Providence, Rhode Island.
Peirce, B. O., Beverly, Massachusetts.
Perkins, Henry C., Newburyport, Massachusetts.
Phippen, George D., Salem, Massachusetts.
Pickering, Edward C., Boston, Massachusetts.

R.

Rice, William N., Middletown, Connecticut.
Rogers, Robert E., Philadelphia, Pennsylvania.
Rossetes, G. R., Marietta, Ohio.

S.

Samson, George W., Washington, District of Columbia.
Scofield, Samuel L., New York, New York.
Seely, Charles A., New York, New York.
Shepard, L. D., Boston, Massachusetts.
Sherwood, Andrew, Mansfield, Pennsylvania.
Smith, Isaac T., New York, New York.
Smith, Rollin A., Fond-du-Lac, Wisconsin.
Smith, Sidney I., New Haven, Connecticut.
Squier, E. G., New York, New York.
Stearns, R. E. C., San Francisco, California.
Stephens, W. H.. Lowville, New York.
Stevens, R. P., New York, New York.
Stimpson, Frederick E., Boston, Massachusetts.
Stimpson, T. M., Peabody, Massachusetts.
Stoughton, T. M., Gill, Massachusetts.

T.

Turner, R. S., Reading, Pennsylvania.
Twining, A. C., New Haven, Connecticut.

U.

Utley, Charles H., Buffalo, New York.

V.

Vail, Hugh D., Philadelphia, Pennsylvania.
Valentine, Benjamin E., Brooklyn, New York.

W.

Walker, Charles A., Chelsea, Massachusetts.
Wanzer, Ira, Lanesville, Connecticut.
Warner, James D., Brooklyn, New York.
Warren, G. W., Charlestown, Massachusetts.
Webb, Benjamin, Jr., Salem, Massachusetts.
Wells, Daniel H., New Haven, Connecticut.
White, A. D., Ithaca, New York.
Whitfield, R. P., Albany, New York.
Williams, H. S., New Haven, Connecticut.
Woolworth, S. B., Albany, New York.

Y.

Young, Charles A., Hanover, New Hampshire.

ADDRESS

OF

BENJAMIN APTHORP GOULD,

EX-PRESIDENT OF THE ASSOCIATION.

MR. PRESIDENT AND GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT of SCIENCE.

THE usage, and even the fundamental law, of this Association entail upon its retiring President a duty which he may not evade: that of delivering at the meeting following his term of official service, a formal address. Although the fulfilment of this duty is but a very inadequate return for the honor which your partiality has conferred upon him, still it is not without its embarrassments, not the least of which is the apprehension of comparison with the utterances on previous occasions by great and honored philosophers who have presided over your meetings. Many of their words were spoken for the children's children of those who listened. Reaching the very souls of those who heard at the moment, they became there endowed with new life and energy, each recipient becoming a center of emanation for what in them was true and important; while they survive upon the printed page for transmission in letter as well as spirit to unborn generations.

Would that I could offer such precious thoughts or incentives for your acceptance. How can I presume to speak as a successor of Bache, Henry, Agassiz and the other great investigators to whom in turn you have confided the guidance of the Association. Yet as their follower, in another sense, I may address you, for I believe that the few ideas which I propose laying before you would find with them approval and indorsement.

With your permission I will speak of the position of the scientific investigator in the community; of the duties incumbent upon him, and of what he may rightfully expect in return, under the present relations of civilized and educated communities; of the peculiar opportunities and restrictions in the United States today; of the obstacles which beset the path of the laborer in scientific fields; and of the results which he may be justified in anticipating as the reward of patient, unfaltering, conscientious effort in his high vocation.

We are accustomed to regard ourselves as belonging to a new country, and to palliate in our own hearts, even if not openly, our intellectual short-comings and our deficiencies in learning or culture, by this plea. And just as men who have attained eminence, notwithstanding an absence of early opportunities, are often accustomed to glory in this want of advantages, as though it had been a merit rather than a misfortune, —judging themselves always by a relative, instead of an absolute, standard,—so we American lovers of science are too much inclined to take note of the difficulties against which we have struggled or are struggling, rather than of the actual level which we have attained by the effort. Of course there is much to extenuate in this proclivity; how much, you all know. The want, until a recent date, of books of reference; the want of access to such implements of research as are beyond the reach of most private men; the want of time and energy to spare from the grand "struggle for existence;" and above all, the want of competent scientific counselers and guides for the beginner in scientific research; all these are well known to those of you who have attained an age at all approaching the meridian of life. Before the omniscient Judge, they will surely be credited to each individual in the great account. But if we consider not the individuals but the people, and hold the community responsible for its collective failures, while we give it credit for its collective achievements, in the intellectual field, I am sometimes apprehensive that we are given to pluming ourselves too much, and to estimating our progress rather by the number of obstacles which we know to have been surmounted, than by the mile-stones which have been left behind. Communities have merits and failings, as individuals have;

they are but the integral of their many constituent individuals; and among our national failings can scarcely be counted that of judging ourselves too harshly. Our aim should not be to overcome difficulties, except so far as this is a necessary means of advance; it is progress, toward which our efforts should be directed, and if the obstacles are serious, we have, as a people, no right to credit merely for having surmounted them, provided we possess, and do not employ, the power to remove them. Can the intellectual standing and rank of a nation be fairly measured by the highest achievements of its ablest and most devoted men, if so be that these men or their deeds are not the legitimate fruit of the tendencies and influences at work, but, on the contrary, are exceptional cases, which have maintained their existence and even blossomed out by virtue of the humanity that was in them, notwithstanding hindrances and discouragements?

Two hundred and forty years have passed since our ancestors sought the wooded hills, the sheltered valleys, and broad meadow lands which skirt the coast of Massachusetts Bay, and amid which we are assembled here. Less than forty miles from this spot, landed the stern pilgrims of Plymouth, eight years earlier. Ten or twelve years earlier still had been founded the English settlement at Jamestown; but it has been the established verdict of history that from the region where we now are, from within a circle not thirty miles in radius around yonder metropolis, may the spread of arts, letters and science be traced throughout this broad land. Within six years from the arrival of the first settlers of the Massachusetts Bay, they voted to establish a college, and appropriated therefore a sum "equal to a year's rate of the whole colony." In the ensuing year they changed the name of the town in which they placed it from Newton to Cambridge, "a grateful tribute to the trans-Atlantic literary parent of many of the first emigrants, and indicative of the high destiny to which they intended the institution they were establishing should aspire." A single year later, John Harvard, a graduate of Emanuel College, Cambridge, bequeathed to the incipient university his library and one-half his fortune, amounting to nearly twice what the Colony had voted. "The example of Harvard," says President Quincy, "was like an electric spark, falling upon materials of a sympathetic nature, exciting immediate action and consentaneous energy. The magistrates caught the spirit and led the way by a subscription among themselves of two hundred pounds, in books for the library. The comparatively wealthy followed with gifts of twenty and thirty pounds. The needy multitude succeeded like the widow of old, 'casting their mites into the treasury.'"

These facts I recall to your memories, to show the length of time during which our national culture has been receiving shape and character. For two centuries and a third, at least, the characteristic, mental and intellectual tendencies of this people have been forming themselves. Our fathers brought with them such culture as the best seminaries of their native land could give; they represented the best intellect of the several classes of the mother country. The professional, the titled, the mechanic and the agricultural classes of New-England were severally of an intellect and culture much above the average of the same classes in old England, whence they came. The standards of scholarship, of science and of art, which they brought across the seas, were the same which they left behind. For the intellectual progress of the world since then, this community has owed its proportionate share, to be reckoned in the joint ratio of its population and of its initial advantages.

True, our people has had the forest, the desert and the red man to vanquish; it has had the social problems to solve, first of a protestant hierarchy, then of independence of all priestcraft, kingcraft and feudalism, and finally of equality before the law, for all who wear the form of man and are created in the image of God. True, it has had its share of trials from foes without and traitors within, and has had the strong bonds of hereditary political and intellectual dependence to burst. True, it has already given to the world many a masterwork, in the arts of peace and the arts of war; the steamboat, the cotton-gin and the sewing machine; the practical application of the electric telegraph, and the means of its printed record; the most perfect forms yet attained for the steam-engine and the steam-boiler; the most powerful ordnance and the most impregnable vessels; the telescopes of Clark and Fitz, the microscopes of Spencer and Tolles, and the means of annihilating pain. True, it has planted the starry flag upon the Antarctic continent and by the Polar sea, and has given to history many a name of the wise and good, whose blessed memory can never be hemmed in by oceans. Heaven forbid that any son of America should shut his eyes to these subjects of honest pride, or to a host of others like them, which I have no need to recount! If love of country be a virtue, assuredly it is not a difficult one for us to exercise. But what I would now say is, that, whatever may be the claims of our country to have done her part in the furtherance of civilization so far as depends upon the solution of high political problems and upon advancement in the arts, her contributions to science have not kept pace with these; nor indeed with those of several European nations, which have had to contend against obstacles quite comparable in magnitude with our own, even though of a totally different nature. France, torn asunder by frenzied convulsions and internal throes, such as no other civilized nation has ever been called on to endure,—Germany, trampled under foot again and again by foreign invaders, civil strife and domestic oppression,—Russia, lately emerged from Asiatic barbarism and contending at once against the Turk, the Tartar and the western foe,—have they not had their share of hindrances to scientific progress, great even if inferior to those offered by the forest and the savage? Yet it would ill beseem us to invite a comparison with them in any department of science, physical or natural. Equate out the names of a very few men on each side, wherever this seem possible, and what an overwhelming preponderance would then throw the Western scale aloft.

"Two hundred and forty years," I hear some one say, "what are they in the development of a nation, or of its scientific character? Twenty-five centuries have passed since Thales predicted an eclipse of the sun; nineteen, since Sosigenes reformed the calendar for Julius Cæsar; fourteen hundred years have rolled over the University of Bologna. What to you occidentals seems a hoary antiquity, is a mere yesterday for the dweller by the Tiber, the Thames, the Seine, the Danube or the

Rhine." Be it so! Yet Hans Lippersheim's first suggestion of a telescope was eighteen months after Newport had sailed up the James river with his infant colony. The idea of a logarithm was then not born: Napier and Briggs were names unknown to fame. The oaks and beeches had been cleared from these hills, and our ancestors had built their rustic homes, at the time when Galileo was tortured into abjuring the profane doctrine that the earth moved, and not the sun. When Harvard endowed the college that bears his name, there was no such thing as a barometer or a thermometer. It is within these very two hundred and forty years that modern science has come into existence, and the world's intellect been turned from speculation to investigation. It is within this period that our implements of research have been devised, that the air-pump, the electrical machine and the clock have been invented, that every public chemical laboratory, every astronomical or physical observatory, and every academy of sciences has been founded. Boston had been settled when Keppler died. The grandchildren of the original colonists of Plymouth and the Massachusetts Bay were born, when the law of universal gravitation was first proclaimed by Newton.

Therefore it is that we must confess our scientific progress to have been far inferior to that of several European nations. And I fear that the confession might truthfully be made much broader, and include our progress in all purely intellectual studies, which hold forth no promise of immediate utility in promoting physical well-being or material convenience. If this is true, my friends, it is time that it should be so no longer. And before you, the declared lovers of science,—in this Association formed to promote her welfare and advancement,—here in the earliest seat of that colony, whence has geographically radiated what of culture and of science our country has possessed,—I would fain say some few words which, however crude or ill-arranged, might find a congenial soil within your hearts—to bear fruit, perhaps, when all of us have disappeared from the stage—and which might aid, in however small a degree, to avert the day when the highest recognized aims shall be toward material prosperity, rather than toward intellectual development and progress.

There must be in every community men specially endowed with scientific tastes and impulses. In most cases such innate tendencies accompany especial gifts in the same direction, and although in the infinitely varied scheme of nature, this is not always the case, yet the exceptions are few, and the incentives to exertion, which such tastes supply, do much toward atoning for the lack of original power. Wherever positions of honor or emolument are available for the man of science, these become objects of ambition or of greed to another class of men who aspire to them as ends to be attained and not as means of scientific progress. It is to such that Schiller referred when he said of science,

> "Einem ist sie die hohe, die himmlische Göttin; dem andern
> Eine tüchtige Kuh, die ihn mit Butter versorgt."*

Between these two classes it is impossible to draw a sharply defined line. They shade into one another by such imperceptible gradations, that many a man might be unable, in his strictest communings with himself, to decide as to which he himself belonged. Then there is an intermediate class, whom circumstance guides into the scientific path and who are endowed with a versatility which enables them effectively to follow out any career to which they earnestly devote themselves.

Now the social problem here evidently is, so to order the influences and attune the public sentiment in the community as to allow the ablest minds to labor in those fields for which they are best adapted, and to guide the most versatile, so far as possible, into such channels that their energies may promote the highest welfare of society.

The magnitude of the class of scientific men in any community is clearly dependent, to a very great extent, upon the intellectual condition of that community. Probably no civilized society, totally devoid of a scientific element, ever did or ever will exist. In ancient Rome its amount appears to have been a minimum, yet in ancient Greece it was far otherwise; whence we may infer that the fine arts and *belles-lettres* are in themselves neither conducive nor antagonistic to science, in any marked degree. At all times and places there have been some in whom the divine fire burned; and so it doubtless ever will be. Such could no more be turned from their high instinct to discover causes and laws, than the mountain torrent from its course toward the sea. Yet how few are these, although they have never failed to pass the torch from age to age! Even in the days of Roman dominion, Africa nursed the embers of the sacred flame; and swarthy Arabs and Moors, with here and there a silent monk, guarded it through the dark ages; ages replete with classic lore, with wondrous art, with barbaric luxury, yet devoid of science, except in the secret guardianship of those who dared not betray their priceless yet mysterious possession.

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* "She is the high, the heavenly Goddess to one; to another
But a convenient cow, that gives him his butter and cheese."

To such men the civilization of today permits freedom of inquiry and of utterance, at least, and awards a certain modicum of public recognition and respect, limited, it is true, not by the good will of the community, but by its means of appreciating the character and scope of their labors. These are the men, nevertheless, to whom indirectly the world owes its material progress, although the intermediate steps, between their researches and the ingenious inventions by which their results are practically utilized, are rarely traced, even by those who reap the harvest. Yet it is not for the sake of material progress that they have toiled; this is simply the world's recompense for having harbored them. *Sic vos non vobis mellificatis, aves.* These are the men who toil on in their lofty studies, seeking the truth for its own sake, drawn as by some resistless magnetism, and working even better than they know. Poverty cannot suppress the instinct; ridicule cannot prevent its exercise; persecution cannot deter from the utterance of its results.

This scanty class constitutes the minimum number of the followers of science for any community. The additional number is greater or less according to the amount of personal sacrifice requisite for following the inborn impulse — since the intensity of this impulse varies in every degree, — or according to the temptations offered for joining the ranks of those who adopt science as a business. It is easy to see that there is danger to the intellectual progress of the community at each extreme. Where the votary of science must sacrifice all to follow her, her welfare is scarcely more imperiled than where the guardianship of her interests, and the means of extending her domain, are confided to the hands of those who would make of her a servant, and not a sovereign.

By an unhappy, though perhaps natural, mischance, the English language has had no name for the scientific investigator, nor word to denote his calling. There is no nobler word than philosopher, — lover of knowledge; yet, in the score of centuries since this grand old word has been in use, its meaning, if not perverted, has at least been narrowed and distorted. The French expression, *savant*, has sometimes been pressed into service by those who have felt the want of some appropriate term; but, without undertaking to criticise the aptness of this word, it is most certain that the time has come when our own language demands some name for the class of men who give their lives to scientific study. Therefore it was, that twenty years ago I ventured to propose one, which has been slowly finding its way to general adoption; and the word *scientist*, though scarcely euphonious, has gradually assumed its place in our vocabulary. Philologically, it is subject to criticism, as being from a Latin root with a Greek termination; but it may share this censure with many another word which has become an integral part of the language, and for a needful and helpful idea surely a poor word is better than no word at all. I will, therefore, not hesitate to employ it, and will briefly consider the characteristics of the scientist, and his position in the community.

It would be inappropriate here to undertake any philosophic discussion of the position which the scientist should occupy in an ideal or a well-ordered society, or of the duties imposed on him by his assumption of the priesthood, as an interpreter and expounder of the Divine word written upon the tablets of the material universe. Such course of inquiry would imply, as its basis, a determination of the reciprocal duties of all members of society, whatever their calling; and this involves, in its turn, the deepest questions of political economy and social philosophy. We must take certain principles for granted, and among them, this; — that civilized society is an organic body, of which each member is, in spite of himself, dependent upon the rest, and exerts a corresponding influence in return. The many-sided culture of a normal community is the resultant of the varied capacities, culture and efforts of numerous individuals, no one of whom could attain the highest grade of usefulness in several diverse departments. It depends upon the relative number and variety of the ablest and most cultivated members, conjointly with the influence they exert. Human science and art have, in the progress of our race, advanced far beyond the comprehension of any individual. An equal culture in many directions is synonymous with superficiality in all, and an "admirable Crichton" is today simply a ridiculous object. We cannot well escape the conclusion that—so far as is compatible with that general education of physical and mental faculties and those general attainments which the welfare of others, as well as the amenities of society, require, and which are needful alike for the mental and moral health of the individual—the energies of each one should be consecrated to the development and employment of particular capacities. No thoughtful man can arrive at years of discretion without becoming aware of the character and direction of his mental powers, even though he may be incompetent properly to estimate their relative magnitude; and there can be no reasonable doubt that taste and predilection would afford safe guides for the individual in entering upon his career, were the organism of society fairly developed without distortion by untoward agencies.

Therefore, if the investigation of scientific questions and the discovery of scientific laws is needful or desirable for our race, it becomes the duty of every civilized community to encourage and protect the vocation of the scientist, and it is the duty of those who feel themselves called to this vocation to devote themselves to it with heart and hand. Their commission is from on high. "Freely ye have received, freely give. Provide neither gold nor silver nor brass in your purses, nor scrip for your journey, neither two coats; for the workman is worthy of his meat." If the Creator designs that the race formed in his own image shall discern and comprehend the laws through which he has exerted his creative power; if he means that his wondrous works shall be read by man, upon whom he has bestowed the means and the impulse to read them; if he chooses that our higher capacities shall be cultivated in this world as well as our lower ones; then does he also intend that a class of men shall exist and be maintained, laboring in behalf of all, and devoting their highest energies to intellectual conquests for the race through the study of his works and the interpretation of his laws. Is there any argument, of all those with which the world has been familiar for more than three thousand years in behalf of the sacred ministry of religion, which is not applicable to the ministry of science? If the highest act of the human spirit be to attain to an intimate relation and communion with the Father of spirits, who shall dare discredit that other exalted duty of searching out God through his works, and learning him as he has seen fit to manifest himself to us directly. Unreasonable as it would be to maintain that the word of God, when filtered through many a human tradition and recollection, and translated from language to language after being recorded upon the manuscript, is more surely and emphatically his unperverted word than is that fresh from his own fingers, "written all over the earth, written all over the sky;" how much more so would it be to maintain, that the former, but not the latter, needs a body of investigators. Far be it from me to imply, however indirectly, that the reverse is true — that the culture of the intellect should take precedence of that of the religious faculties — that the most elevated regions of converse with the Deity as known through his noblest works, or his profoundest physical laws, could supersede the necessity of communing through the affections and emotions, or the need of relief to the famishing cry of the soul for bread from its Father in Heaven. It might, perhaps, be urged that for the former a priesthood is, and for the latter it is not, indispensable; that for the former the progress of interpretation goes on continuously, while for the latter little remains to be done, other than the exposition and enforcement of what has already been attained; that the former must lead, while the latter is not unlikely to follow, the development of society. But there is no ground for comparison disadvantageous to either class. My argument is that they should stand alike. Both classes are needed to satisfy a deep and insatiable demand; both are imbued with the instinct to provide a supply. Nor are the abnegations and self-sacrifices by which the one has earned the martyr's crown in past days and lasting reverence in the present, without parallel and counterpart in the other.

With what a spirit of grateful recognition of the Almighty's revelation to the scientist in these latter days, may we read the answer to Job out of the whirlwind!

> "Gird up thy loins now like a man, for I will demand of thee, and answer thou me. Where wast thou when I laid the foundations of the earth? Declare, if thou hast understanding. Who hath laid the measures thereof, if thou knowest; or who hath stretched the line upon it? Whereupon are the foundations thereof fastened, or who laid the corner-stone thereof, when the morning stars sang together, and all the sons of God shouted for joy? . . . . . Hast thou entered into the springs of the sea, or hast thou walked in search of the depths? Hast thou perceived the breadth of the earth? declare, if thou knowest it all. Where is the way where light dwelleth, and as for darkness, where is the place thereof? . . . . . Hast thou entered into the treasures of the snow, or hast thou seen the treasures of the hail? Knowest thou the ordinances of heaven? Canst thou set the dominion thereof in the earth? Canst thou lift up thy voice unto the clouds that abundance of waters may cover thee? Canst thou send the lightnings, that they may go, and say unto thee, Here we are?"

Job answered and said: —

> "Behold, I am vile, what shall I answer thee? I will lay mine hand upon my mouth. Once have I spoken, but I will not answer; yea, twice, but I will proceed no farther."

But we might reply: — 'Lord, thou hast revealed unto us all these things. Us also hast thou taken into the counsels of thy creation, for thou hast not deemed thy children unworthy of thy knowledge. The foundations and breadth of the earth and the ordinances of the heavens, the depths of the sea and the way of the light, the treasures of the snow and the sources of the hail, the sending of lightnings to say 'Here we are,' and the lifting of our summons to the clouds that we may have rain; — behold thou hast disclosed them all unto us, thy children!'

The claim of the scientific profession to recognition and support has long been acknowledged by most European nations. Throughout the European continent organizations have been established, and are maintained by the government at very considerable expense, for the one purpose of promoting scientific research; and the individuals composing these organizations are provided with the means of support while laboring to this end. In our own utilitarian country few claims are recognized excepting such as afford a direct personal benefit, which the individual recipients can estimate by some pecuniary standard. Thus the successful investigator in any special department of medical science may reap a rich reward,—so rich indeed as to hold out strong temptations for the surrender of so large a share of his time and energies to the practice of his art, as to leave small opportunity for the farther prosecution of his science. Indeed, when we examine the matter carefully, we shall find that it is only art (*i. e.* the application of principles and laws), for which any practical recognition can be expected in America at present; while science (*i. e.* the discovery and investigation of these laws), even where nominally fostered, receives support only through some of its indirect branches, which more properly belong within the domain of art. In this way medical science in this country is supported only through individual need of the healing art; physical research, only through its most direct application to technology; mathematical investigation, only in so far as it stands in palpable relation to engineering, surveying, or some other practical use; chemistry, as being an important handmaid to manufacture and to metallurgy; astronomy, almost solely as an assistance to navigation. To one considering these unquestionable facts, the parallel case at Niagara presents itself unbidden:—

> "The tailor made a single note:
> 'Gods! what a place to sponge a coat!'"

In recounting these facts, it is without apprehension that they will be scouted, by any educated and thoughtful man not versed in scientific matters, as though they presented the one-sided view entertained by a narrow class of persons, who, from habitual occupation with abstract or general inquiries, have become blinded to the great material interests of society. No doubt the advance of civilization is measurable by the progress of the arts; and especially is our nation charged, as no nation ever was before, with the duty of subjugating nature, and diffusing the arts of civilized life over a continent. No doubt the first instinct of humanity is to provide for its material well being; and the craving for comfort and luxury is a stimulus at whose bidding the whole world is to be made one family, through the beneficent agencies of commerce. But I do claim, first, that we have reached a stage at which it behooves us to acknowledge a higher aim, as much beyond the commercial and technological as the intellect is beyond the body: that the aim is dictated to us by the Creator through intellectual incentives and opportunities, and that its pursuit is unfailingly rewarded by material recompenses. And, secondly, even if we disregard these considerations altogether, and take into account merely that material progress to which America is devoting all her energies, that it is a narrow and baneful policy which forgets that immediate, direct and palpable influences are not the only ones. Rarely are they even the chief ones.

It would be throwing words away were I to undertake to prove, what you all know already, that scarcely one of all the great advances in the material welfare of humanity would have been made but for the scientist in his closet, whose experiments, researches and generalizations, incited by the love of nature and the aspiration to fathom her laws, have afforded the knowledge which the inventor's fertility of device has made subservient to human welfare. There is no need of balancing the respective merits of the discoverer and the inventor. All will agree that but for the former the latter would be of little use. To be sure it would be false reasoning to maintain that, because valuable inventions are usually due to scientific discoveries, they must be deemed a necessary consequence thereof. Yet experience points to some such conviction; and it would be difficult to point out an important scientific discovery, no matter how abstruse if twenty years old, which has not already conferred some material benefit upon humanity, and which was not itself dependent upon each one of several independent and seemingly isolated previous researches.

It is not then alike the wisest policy and the evident duty of a people already much advanced in material well-being, and ambitious of progress, that it should recognize the debt it owes to science, by courting such opportunities for the future as science may afford? Is it not among its most palpable duties to develop and encourage scientific tastes and investigations, appreciating the material sacrifices which these entail, even under the most favorable circumstances? Is it not discreditable to the civilization of a great people, when scientific ability is habitually stifled or lost, by want of opportunity for its development? Yet a tale might be told, year after year, of earnest and gifted young men compelled by want of bread to abandon the scientific path upon which they had entered with fervor. And if told, I believe it would astonish those whom circumstances have not inured to the facts, as it would mortify and sadden the patriot and the philanthropist. It is to be expected that the pursuit of wealth, or place or power, should have its own reward; the sincere follower of science neither seeks nor expects any of these things. But, unless the idea that a community can have duties and responsibilities, as well as an individual, be preposterous, the competent and willing votary of science is entitled to the means of investigating while he lives, and of living while he investigates. In all this broad land I know of not half a dozen positions, the duties of which may be discharged and a subsistence earned by prosecuting scientific research. What is done is in the intervals of leisure from other labors, which exhaust the energies, but upon which the investigators are dependent for support. The collegiate professor, whose nervous vigor is expended in the task of instilling trite rudiments into the minds of enforced pupils, forms no exception to this statement. And where are the opportunities for those higher teachers who would fain use the blessed privilege of training others for the scientific vocation, and be rewarded by the consciousness that their conceptions, methods, plans and perhaps conjectures, are not to die with them.

It would be far from reasonable to expect that the labors of any considerable proportion of investigators should be severally crowned by large generalizations, or by such discoveries as are subjects of popular appreciation. These are comparatively rare, and have always required the antecedent researches of a series of investigators to whom history is wont to award inadequate acknowledgements. Stones must be quarried and hewn before the edifice can be reared; facts must be gathered before their laws can be discovered; the several laws must be recognized before their generalization can be effected. The function of the scientist is to attain new truths by conquering them from the limitless realm of the unknown, and whether they be brilliant or otherwise, none is too small or insignificant in aspect to deserve his earnest search or joyful welcome. Among the marked characteristics of modern science are its recognition of the value of every observation and experiment,—since there is no one which may not afford a basis or a clew for subsequent advance,—and its appreciation of the services rendered by those who lay the stepping-stones requisite for continued ascent. And in proportion to the scientific development of a community is its relative estimate of the men who do not disdain those minor researches which are yearly becoming more indispensable, yet are unrewarded by popular applause. The science of the nineteenth century is to be sought not in ponderous tomes, but in abundant memoirs. Scientific progress in these days is like that of a besieging army. Little by little miners work beneath the surface; slowly the intrenchments grow to right and left, approaching always, however indirectly; gradually the long circumvallations close around the citadel. Here, ground is gained for a new base of operations; there, is opportunity for striking in a new direction. Through avenues thus laboriously prepared the embattled host advances. At last a point is secured whence the artillery may begin its work. Under cover of this, new approaches are effected, until at last, in the fullness of time, the final charge is made. One brilliant dash, and the stronghold falls. But should the engineers' devices, the miners' toil, the soldiers' labor at the earthworks and the artillerists' service at the guns, all be held cheap, because of our admiration of the gallantry and chivalry that led the decisive onset? So thoroughly has the scientific world been impressed in recent years with the importance of judging researches not by their brilliancy, but by their promise of ultimate usefulness, that the straining after showy results is deemed unworthy and derogatory, while a new and well established fact is welcomed with a more earnest cordiality than the most fascinating hypothesis, or the most plausible conjecture, prior to its verification.

All science is, and must be, to a certain extent, experimental. Even in those branches which from their very nature preclude arbitrary experiment, comparisons of phenomenon with prediction, of observation with computation, supply its place. Methods of discovery, in astronomy and in chemistry or terrestrial physics, differ but little. Keppler's mind was scarcely of a different order, or his processes of a different class, from Faraday's. And, essential as the inductive method may be for a control and criterion of the results attained, few discoveries were ever made by pure induction. Given the result in advance, experiments may be contrived for guiding to it; let us once know that the truth lies in one, and one only, of two divergent directions, and we may think out crucial instances. But such are not usually the circumstances under which discoveries are made; and learning and skill are in general no more necessary for disposing of hypotheses, than is ingenuity of invention for framing them.

The facts and relations to which I have called your attention indicate the functions of the scientist in the present condition of our civilization. The duty of investigating the principles and laws of the material universe once conceded, this office devolves, in the grand division of labor, upon a special class. And that stage of progress is already attained, in which subdivision in a high degree, among this class, is imperative. Large acquaintance with kindred branches of science, and special concentration of effort upon a narrow field, are alike requisite for the investigator. Moreover he must be content with small and modest additions to human knowledge; humbly and hopefully gathering what he may, and bringing faithfully his sand-grains to the heap, if he find no stone for the temple. He may no longer look for brilliant discoveries as the sure reward of earnest research, though he should possess the genius of Pythagoras, Archimedes, or Copernicus; nor have others the right to expect it of him. And if perchance any such discovery or generalization fall to his share, simple justice demands that he concede to others much of the merit. The activity and energy of scientific inquiry at the present moment are intense beyond all precedent in history. The accretions and developments of a couple of years change the aspect and relations of each successive discovery almost past recognition. An important fact, noted but unpublished by one man, speedily manifests itself to others; so that suppressed discoveries are in fact abandoned ones, and the most important are very frequently made in duplicate. This is simply because the limit of our human knowledge spreads like a great circular wave, emanating from a center. The advancing lines have access only to what lies upon the margin before them, and the throng who press forward tread in contiguous paths, the divergence of whose radiation is overbalanced by the continually increasing number in the ranks. And it is characteristic of the present time that it is a period requiring co-operation and associated effort in scientific research, not merely for the sake of needful distribution of labor, but because combinations of resources and acquirements are requisite, to which no individual can attain.

It would be a grateful office to congratulate you upon the part our own people is taking in this great campaign for intellectual conquest. Thank God we may claim some part in it, and names too, among the living as well as the dead, which will surely gain lustre in scientific annals with the lapse of time. Yet how small is our relative share! Why have we not, in our forty millions of men, as many active investigators, as many scientific institutions, as much national support, as much popular sympathy, as may be found in Germany, France, or England? Why are the efforts of the scientist appreciated and encouraged solely in proportion to the estimate of them by popular and altogether incompetent tribunals? That it is so, needs no demonstration. Popular sympathy or encouragement rarely rewards the scientific investigator while living; and when it does, it is seldom because of his highest achievements. And those rewards, which the community honestly desires to bestow upon this class of intellectual labor, are but too apt to fall to the mere bookwright, if not to the charlatan. Meanwhile great public interests suffer for want of such guidance as very many easily might, and gladly would, give who live and die unrecognized by those who would desire to make their services available, and whose recognition would augment their usefulness a hundred fold.

Do you ask the remedy for this disease? I know none, except such change in public sentiment as may lead to deference, in scientific matters, to the judgement of experts, together with the maintenance and encouragement of institutions which may serve to develop experts and indicate who they are.

It cannot be denied that there is a large class with whom strong antipathies exist against scientific pursuits, and against those who are habitually engaged in them. For these prejudices there are various reasons, some by no means unnatural. That continual demand for evidence, which scientific studies evoke, is peculiarly distasteful to the vague and purely speculative mind, and affords a never-failing subject for ridicule. The very warfare in which the reverent votary of science sometimes finds himself involved in defence of her interests—so paramount in his estimation to his own—is made a ground for imputations of irritability and jealousy. The mere utilitarian objects to the abstractions of the higher sciences, as unfitting men for the daily duties of life; ignorant himself of any utility or duty which does not lie upon the surface. And then there is a counter-prejudice even among some educated and thoughtful men, which regards all studies pertaining to the physical universe, as of a low order and "materialistic" tendency, and which actually despises all inquiries, the correctness of whose results may be tested.

How far just foundation may exist for any of these adverse judgements, I will not undertake to say. There can be no doubt that exclusive attention to any one class of pursuits, will give onesidedness to the character, as well as to the culture; yet I am not sure that scientists are more justly subject to this criticism than any other class of men. Indeed it might be claimed for them, with a fair show of reason, that as a class, they are more familiar with literature, philosophy, and the arts, than the followers of these vocations are with science. Certainly they are better acquainted with the practical affairs of technology, than the so-called "practical man" is with scientific matters. And if the tenor of their studies lead them to distinguish sharply between what is, and what is not, susceptible of proof, and thus to lose some of the genial influences of imagination through their quest of the ennobling influences of truth, they may perhaps be thereby rendered less agreeable companions, yet they are none the worse citizens.

But all the opposition to scientific studies, springing from such considerations as I have named, is small compared with that from theological sources. From the very dawning of modern science, the various systems of theology have waged against it an unceasing war. The demonstrable character of its results have rendered it especially obnoxious to those who feared some encroachments upon their prescribed tenets, or who dreaded lest the overthrow of some favorite theory might be fatal to all reliance upon their creed. Some have assumed an antagonism between the orally and the visibly revealed word of God, and in their solicitude for the former have attempted to discredit the latter, and summoned to their aid the whole battery of the casuist. But they have forgotten that excess of zeal is abortive, whether it be in behalf of science or of religion, and is sure to create a reaction injurious to that cause in behalf of which it is exhibited.

I remember thirty years ago hearing a venerable and good man, who stood in the front rank of our scientific teachers, preface his lectures on geology with a deprecation of its "infidel" tendency when not properly interpreted. And the days are by no means past, when the efforts to reconcile apparently conflicting statements, in the book of Genesis and the book of Nature, are far more strenuous than any efforts at verifying the credentials of either statement. The inquisition of two decades ago took a different shape from that of two centuries earlier, but it was scarcely less tyrannous or unrelenting. That agony of nerve and muscle, which wrung from Galileo Galilei his transient recantation, was scarcely more severe than the mental and moral pangs, which more than one man of science has been called upon to bear in our own day, because he has become convinced that our earth existed thousands of centuries ago; that all mankind are not descended from a single pair; that the evidence is decisive that human beings lived during the pleiocene period; or that the sun antedated the earth, and its alternations of day and night.

All this is changed in our seminaries of learning today, I admit. In the meridian blaze of scientific knowledge, and the diffusion of its life-giving energy, such darkness could not continue. Yet how short the interval since its dispersion! Revulsions of popular feeling are like the oscillations of a mighty pendulum. Reaction has now in turn overshot its mark, and today it is theology which stands on the defensive. Even that attempted compromise, which would leave to scientists all things scientific, and to theologians all things theological, although in its nature unstable, has failed to find that temporary acceptance which might have been anticipated for it.

Thus the conflict, between accepted creeds and facts claiming to be demonstrable, is one which may no longer be delayed. No temporizing will avert it more, and one or the other must yield. Truth, though many-sided, cannot be discordant, and the honest man desires to know and to accept it. No evidence for any theory can be satisfactory, so long as evidence on the other side cannot be disposed of. The student of nature deals, it is true, only with material facts; yet his results, such as they are, are demonstrable, and may not be discarded to suit the preference of any sectarian. On the other hand, theological and philosophical inquiry deals only with moral evidence and with mind; yielding results which rarely admit of actual demonstration. With a strange avidity, the name 'science' is constantly claimed for researches in these fields, as though no other word were equally honorable; still it is relatively only a very small portion of them to which the term may be rightfully applied, since it implies the investigation, not of facts alone, nor doctrines, but of laws. And although unquestionably there have been, and may be, elicited in this field certain laws, yet their paucity is recognizable by the criterion that what is once established must be accepted by competent minds, and adopted as a basis for farther research. To deny the laws of gravitation, of the tides, of storms, of magnetism, is merely to manifest ignorance. Yet the multitude of diverse systems of philosophy and of religious creeds has been increasing, not diminishing, for the last two thousand years.

Still it may not be denied that we have two independent means of attaining knowledge of the higher truths. These imply totally different methods, and should reciprocally confirm each other, if their results be correct. Let the existence of a real conflict in their results be once established, and their is no escape from the inference that at least one of them is erroneous. Now although mistakes in scientific deductions are frequent enough, no sane man will contend that those results are erroneous, which may be proved to the acceptance of all competent investigators who examine the question. And those, who war upon all scientific investigation of theological questions, must either object to competent evidence, or must plant themselves upon the dangerous ground that all physical evidence is inadmissible.

In what I am saying I am sure no one will suspect me of the slightest intentional disrespect to the religious convictions of any earnest believer, however conservative or however liberal. Yet we are continually brought to the old, old dilemma, where science seems to demand one inference, and faith another. To accept either, if hopelessly contradicted, is repugnant to the philosophic mind; how to reconcile them, has been the problem of the ages. The apparent antithesis may be variously stated. One man presents it as between Nature and Revelation; the latter certainly divine, the former in its essence illusory. Another puts it as between Science and Religion; the former ignoring the moral, and the latter the perceptive faculties. A third gives it as between the evidence of the Senses and the intuitions of the Soul. Bigots, casuists, fanatics, have each in turn assailed the teachings of science, and have swept along with them many a good and earnest man whose fervid piety has led him to glory in the motto '*Credo quia impossibile est.*' Vague arguments, in which words and ideas have become almost inextricably confounded, have alarmed the consciences of men, lest the rewards of faith should be withheld from those whose faith required no sacrifice of reason. Meanwhile it has been forgotten, both that there must be some apparent reason for one's faith, and that faith and reason are alike expressions of the Divine in man. To such an intensity has bigotry continued even in our own days, that we may see the mischievous sophistry yet maintained in some quarters, that there are moral limits to inquiry, which man may not presume to transcend; before which scientific research is unlawful, and theological inquiry sinful. What could impel to such doctrine, except an apprehension of those results to which honest research might lead? Were the prohibition addressed only to a class deemed incompetent to investigate intelligently, or whose preliminary knowledge was inadequate, we might appreciate and possibly approve it. But this is not its spirit. It is either an assertion that the Almighty cannot guard his own secrets, or else it is an assertion that the All-wise and All-powerful has imbued us with quenchless aspirations, and has established incentives which cannot be followed without leading us away from him. Before modern science existed, while superstition held unchallenged sway, when dealers in the black arts of chemistry, astronomy, and the like, were conceded to have sold their souls to Satan, such a doctrine might not have surprised us. But that educated partisans of any creed should maintain today, that obedience to the God-given instinct of searching out the laws and being of the Almighty, in his physical and moral creation, is a crime, and that the tree of knowledge still bears fruit which it is forbidden to gather, in however reverential a spirit, seems a horrible anachronism.

If there be one moral truth which may be regarded as beyond all question, it is that our worship belongs to the author of nature, who fashioned alike the body and the soul of man, and is sovereign over all matter as well as all spirit. Yet the separation between scientific and religious views of the universe has been growing wider for a century, impelled by the joint efforts of the bigot and the atheist, who have worked most earnestly together for their common object. Never was the need so sorely felt for the discovery and recognition of that middle term, which must exist, and through which the dissonant views are reconcilable.

One of the clearest thinkers of our time believes that he has found such a middle term, and maintains with vigorous argument the doctrine that it exists in Force. And among its varied and correlated manifestations he claims that it nowhere finds a simpler or higher manifestation than in Will,—the only form which may claim to be primary. Here we enter upon a theme so lofty and so dizzying in its height that we may well distrust our powers; and in the unwonted keenness of our sense of their inadequacy, we feel how closely we are treading upon the margin of their range. Yet I will venture to say a few words upon this point, because I find myself alike unable to resist the conviction that a great verity underlies the idea, or to accept the doctrine as consonant with what may be regarded as demonstrated concerning the nature of force; notwithstanding the ability with which it has been maintained by a certain school of philosophers, that life, consciousness and all psychical energy are simply manifestations of this same force,—convertible into and deduced from heat, chemical action and the like.

Scientists are now of accord that "force can neither be created nor destroyed," and that "the quantity of force in nature is just as eternal and unalterable as the quantity of matter." Its various forms are eminently convertible, yet utterly indestructible. And to avoid that fruitful source of disagreement among the ablest men, which has arisen from the ambiguous signification of the word, we must adopt the meaning which is finding general acceptance, and define force as "that which is expended in producing or resisting motion;" thus clearly discriminating between force and its cause.

In his retiring Address before this Association, last year, our honored ex-president Dr. Barnard presented an argument, so vigorous and clear that I see no room for an adequate rejoinder, in opposition to the doctrine which would extend the principle of the conservation of force to the phenomena of consciousness,—"a philosophy which at the present day is boldly taught in public schools of science, and which numbers among its disciples many very able men." He says, for instance:—

> "Organic changes are physical effects, and may be received without hesitation as the representative equivalents of physical forces expended. But sensation, will, emotion, passion, thought, are in no conceivable sense physical."—[*Proc. Amer. Assoc., Chicago, p.* 89.]

> "The philosophy, which makes thought a form of force, makes thought a mode of motion; converts the thinking being into a mechanical automaton, whose sensations, emotions, intellections, are mere vibrations produced in its material substance by the play of

physical forces, and whose conscious existence must forever cease when the exhausted organism shall at length fail to respond to these external impulses." — [*Ibid*, *p.* 91.]

"Thought cannot be a physical force, because it admits of no measure. . . . A thing unsusceptible of measure cannot be a quantity, and a thing that is not even a quantity cannot be a force." — [*Ibid*, *pp.* 93, 4.]

Before the cogent reasoning carried out by President Barnard, of which the general tenor is indicated by these quotations, the view that force affords a middle term between the moral and the material worlds can be sustained as little as the pure materialism against which the argument was directed. But if we ascend a grade higher, and consider that which guides and compels force, as force guides matter, I am disposed to believe that the problem may be nearer to a solution. Yet I offer my views with hesitance, not unmindful of the great thinkers who have considered these exalted topics, and shrinking from the rebuke of presumption.

There is an elegant experiment, in which the tension of a spring is made to produce heat by percussion, thus developing the current from a thermo-electric battery, which by successive modifications of its force exhibits heat, chemical action, magnetic attraction, and finally bends another spring; the same original force successively appearing in all these various manifestations until it is reëstablished in its primitive form. In such an experiment the imperfections of the apparatus would of course entail some loss at each successive step, and thus preclude the practical recovery of an available force equal to that expended in the original flexure of the spring. Yet the fact is beyond question that such loss is due solely to the inadequacy of our implements for collecting and transmitting the force at each stage of the experiment; for the law of conservation teaches that it is in every instance converted into other form or forms without diminution. Could such an apparatus be constructed with theoretical perfection, it would represent an eternal circuit of force; and, like the frictionless pendulum in a vacuum, it would exhibit a perpetual motion, after the needful impulse had once been applied. The spring would oscillate forever, did no extraneous force oppose, whether the force producing its rebound were or were not transmitted through a chain of modifications.

In this inert apparatus no force whatever would have been embodied, yet qualities would have been implanted by design, which would compel an indestructible force, applied to it, to play the part of an unwilling Proteus. The influence seems unavoidable that force may be guided and controlled, compelled to exert itself in this or in that shape, without the outlay of any other force for the purpose. If it be objected that it is an intrinsic law of force that it shall change its form in exerting itself, the case is in nowise altered by the expression of this truism. Our design has prescribed, and (extraneous force being absent) might indefinitely prescribe, the modes and directions in which that constant force should manifest itself.

Muscular force is directed, and in its vital action is usually controlled, by will. If we assume it to be coequal with the expenditure of tissue,* measurable alike by its transferred results and by the decomposition of this tissue, where and what is that power which lets loose or withholds this force, and whose action is attended by a conscious effort? It is the will, —a something which directs and controls force without expending it. Not only are thought and forms of consciousness not forces, if the reasoning already adduced be correct, but, although often moral incentives to the will, they are not even motive energies, in the sense in which I think we must concede the will to be such. It is true that the exercise of thought is followed by fatigue, yet it is not attended by a sense of effort, except in so far as it is directed by an exertion of the will. And although the former doubtless consumes tissue, have we any reason for believing that the exercise of will does the same, apart from that consumption which corresponds to the forces whose mode of action it prescribes?

Thus it would appear that the metamorphosis of force, though not "work done" in the mechanical sense, is the result of some definite mode of causation. What this causation is, and whether it is susceptible of measurement, are the next questions. In the same category with this agency, or energy, or influence, the vital principle would seem to belong,—directing forces while it neither expends nor consumes them. In the growth of organic beings, unstable combinations are formed, and organized structures are thence reared, in which, as Kant has so beautifully said, "all parts are mutually ends and means." If in such organic development force is consumed, disorganization without decomposition ought to evolve it. Of the deposit of force in the unstable material of the tissues, I am not speaking, but of the vitality itself, which represents an energy requisite for the development and growth of organisms, —their dissolution being in turn attended by development of inferior forms of life, which suggest that this energy may have again been made available,—an energy too which is not "force," as this term has just now been defined.

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* Even if it be also, to some extent, supplied by the disorganization of food not fully converted, the argument is not thereby affected.

No comparison can be drawn between vitality and those molecular forces which build the crystal. Crystalline forms arise when the molecular attractions enjoy the freest scope, and their construction must be attended by an evolution of force, which ought to be recognizable by physical tests, and which should also be measurable by an excess of their resistance to solution, over that of comparatively amorphous masses of the same material, in which equal weights present equal surfaces.

So, too, not only in that individuality which life confers and in the impossibility of insulating or transferring vitality, but also in its hereditary character and its apparent susceptibility of indefinite increase or diminution, the vital energy violates our fundamental conceptions of force, and demands a separate category, seeming to belong in the same with will. If will and life be forms of force, their total amount must be limited by the law of conservation. If, on the other hand, they are outside the realm of forces, we may more readily indulge the conviction to which experience would lead, that their freedom is unfettered by any restrictions within our knowledge,—each enjoying an indefinite, though possibly a correlated scope in its own domain. The indestructibility of both matter and force implies a fixed coefficient of force for matter in equilibrium; but how great is the contrast offered in this respect by such energies as life and will!

Now if this reasoning be correct, we may have in this class of energies that middle term, so earnestly desired and so intensely needful, which unites the phenomena of matter with those of spirit, and forms the connecting link between science and religion; their harmonious conjunction affording the highest system of philosophy. It is this class of energies which, controlling the forces of matter, guides and governs their modifications and transformations. It is this, moreover, which, inseparable from mind, is exerted by all conscious organism. The mystic play of coequal, but to our senses, so dissimilar forces, and the equally recondite mutual action of the eye, the brain and the nerve, alike demand agencies transcending all our science, yet implicitly obeying physical laws. The highest manifestations of these agencies is in will; the highest agent is the Almighty. Thus the dictum of faith, that the universe exists only by virtue of the continued will of its Creator, represents a palpable scientific fact; and we may see that the pantheist, the materialist and the spiritualist (I will not be debarred from this noble word by the associations of its misuse today) have been contemplating the same exalted truth from different aspects, with limited ranges of vision.

With the disappearance of theological hostility to science, a new era will commence, and increased progress may confidently be expected both for science and for religion. But we may not conceal from ourselves that the omens are less favorable for science in our own land than elsewhere, since there are peculiar obstacles to be encountered. These chiefly arise, directly or indirectly, from that characteristic in our national development, which assigns an exaggerated value to immediate utility, and a low estimate to what real utility is. It cannot be denied that the attainment of riches is becoming with us more and more the chief aim of existence; and this tendency is aggravated by that dominant spirit in our large cities, which gives to wealth alone the influence which it ought to share with integrity, with refinement, with education, and with talent. Thus the ambition of our youth is almost irresistibly directed to the acquisition of property as the highest worldly good, and their experience is made to confirm the doctrine. Our institutions of science, few as they are (and almost universally confounded by the public with institutions for the preliminary education of youth), are, like the latter, dependent upon subsidies and gifts from individuals. A disposition to advance the public welfare by liberal munificence, may certainly be claimed for our wealthy classes, and America has a right to abundant pride in the generosity of her rich men; yet it cannot be expected that largeness of views in literary or scientific matters should always be commensurate with largeness of heart; and the monuments of unwisely directed generosity, scattered all over the land, commemorate gifts, which, if judiciously bestowed, would probably have placed the United States in the front rank of intellectual progress. But, more than this, these same influences have resulted in placing, to a very large extent, the governance and guidance of intellectual agencies, and the control of intellectual institutions, in the hands of men not well fitted for their exercise. How could science, or literature, or art thrive, while their interests are in the keeping of those who do not comprehend them, and who, even with the best intentions, do not know at what to aim? The administration of the finances of an institution loses much of its value, when the institution itself goes adrift. And then again, while it has been and is still the usage to do all we can for the education of youth up to a certain point, no encouragement or support has been deemed needful beyond that point; so that in fact the individual is aided in preparations for usefulness, but receives not the slighest encouragement for the actual exercise of that usefulness, after the preparation is completed. In late years we have actually retrograded in this respect; and, even in seminaries of education, discouragements are thrown in the way of those studies which do not suit the views of the utilitarian. But in America today, the crying need is of opportunities to make serviceable such preliminary training as may have been acquired in any purely intellectual or scholastic field — a need far greater than any lack of opportunity to obtain this requisite education. It has become forgotten that the training of the school and the college is but a means, and not an end; and, as in so many other cases, the end is lost from sight in the pursuit of the means, — the prosecution of research is neglected, while the requisite education is zealously provided for. Thus it is that the scientist is compelled, almost without exception, to earn his bread independently of his vocation, that is to say, by work other than scientific research. Finally, the want of any recognized tribunal, whose judgement might be provisionally accepted upon matters requiring scientific knowledge for their decision, which might command public confidence by the character and attainments of its members, and which could represent, advocate and maintain the interests of science with the public and with government, has till recently been a source of disadvantage, which it would be difficult to overestimate.

The extent to which our people has indirectly suffered from the want of recognition and support of scientific pursuits would scarcely be credited at first statement. The lack of those mental habitudes which they imply, is a fruitful parent of superficiality, and is largely accountable for our national fault,—want of thoroughness; for thoroughness will never flourish while only those pursuits are encouraged which promise immediate recompense of the most tangible sort. Another result is the absence of deference to competent authority, the absence of respect for mental excellence and power. To become aware how little we know, requires some progress in knowledge; and, just as want of faith brings superstition, so disregard or ignorance of known laws begets credulity. What ludicrous illustrations of this fact are daily offered by the vague popular conceptions of the well-known laws of electrical action. I have heard it said that the most complex processes are suddenly revealed and made clear to the feminine mind by the magic word "machinery." Be this true or not, it will scarcely be denied that to the masculine intellect there is a cabalistic virtue of equal potency in the mysterious name "electricity." To this awe-inspiring agency — although no more recondite for the physicist than heat or light or gravitation — all uncomprehended facts are attributed with a sort of satisfaction to that reference to supernatural powers is thus evaded!

The recently prevalent belief in ghostly table-turnings, supernatural knockings, rappings and bell-ringings, and in spiritual lead-pencils, would furnish also a painful illustration of my meaning, were it not still a somewhat dangerous subject to discuss with freedom,—even out of Salem!

Prominent among the serious dangers which are theatening the welfare of science among us, at present, is its advocacy upon improper grounds. That man is no loyal follower and no true friend, of science who bases her claims to support upon the ground of immediate practical utility. How essential she always has been to the useful arts, all history and experience proclaim; yet these recompenses would form indeed a low and unworthy motive for her pursuit. To follow her for such an end would be to follow a Divine leader for the sake of the loaves and fishes, expected to be miraculously dispensed to hearers of the word. To hear that word, to learn that law, to gain some comprehension of the lofty scheme, such are at least the only motives worthy of avowal. The present reaction from the era, when all culture other than classical and metaphysical was disregarded if not despised, and the crusade against classical culture, which results from this excessive reaction, bode no good to science. The champions in this crusade occupy simply the utilitarian ground, and their alleged advocacy of science is in fact scarcely more than an advocacy of the useful arts as the highest object of education or of the attention of the educated classes. The crusade is not in behalf of this or that form of intellectual progress; it is against such intellectual culture as has not some tangible end, capable of being represented by dollars, or finding expression in some form of physical well-being. Results of this outburst of utilitarianism, combined with worship of Mammon, are already visibly manifested all around us in the substitution of expensiveness for elegance, of monstrosity for grandeur, of gaudiness for beauty, of quantity for quality. As the golden age degenerated to the iron, so the age of iron has dwindled into that of tinsel. See, in so many public buildings, how tawdry contrasts in color, or extravagance in ornamentation, usurp the place of beauty in form. See, in public grounds, how the grace and harmonies of nature are ostracized, for the sake of putting something expensive in their place. Even the reverence which would fain preserve and protect what is hallowed by associations and memories of the great and good is regarded as a conservatism, quite "behind the times."

To save our country from the abyss, on the verge of which it stands, will require all the energies which can be summoned; yet we have the satisfaction of knowing that, with few exceptions, the most refined and cultivated men of the land recognize the danger and are united in efforts for its aversion. Science has few stronger friends than among the scholars of America; scholarship, few more zealous adherents and admirers than among her scientific men. Intellectual culture, of any sort which aims at something higher than narrow utility, is what we need, and its advance in any one direction can scarcely fail to be followed by advances in others. Scientific education, moreover, peculiarly requires fullness of culture; and whatever hampers this, obstructs the progress desired. The experience of ages may not lightly be disregarded, and we must remember that novelty is not necessarily excellence in philosophy, education or art.

But there is a pleasanter side to the prospect; for, where science does have a foothold, her path is becoming smoothed and the sphere of her influence extended as never before. In scientific matters at least, we are attaining the epoch of simplicity, which entails universality, and this in its turn promotes the brotherhood of all who serve a common cause. The magnificent discovery of the correlation of the physical forces weaves the physical sciences into harmonious relationship, and opens to our vision glimpses of still grander generalizations beyond. Recognition of the equivalence of these different forces entails the introduction of absolute units which command universal acceptance; and thermic, electric, magnetic, chemic, mechanic energies are gauged by units depending on the meter and on the earth's rotation. The metric system of weights and measures, already of almost universal use for purpose of research, is rapidly finding popular adoption among all nations, notwithstanding the force of prejudice and the reluctance to modify habitual usage. Thus the nations are entering into more intimate intellectual relations with each other, at the same time that, by the progress of the arts of life, the physical barriers which separated them are broken down, and the sharpness of dividing lines is softened.

It would be unjust too, did we fail to acknowledge the influences by which trade has not unfrequently exerted a most healthful stimulus upon scientific research, when the requirements of the arts have pointed out the directions in which farther knowledge is especially needful for their purposes. The wonderful additions to our knowledge of the laws of electrical circuits, which have been evoked in England by the direct influence of companies for the manufacture and use of submarine telegraph-cables, furnish a brilliant example of what may be accomplished in this way. And of a quite analogous character are those national influences and characteristics which tend to the especial promotion of particular branches of science, and, by the reciprocal and reflected action of these upon the tendency thus implanted, render it markedly prominent. Thus the need of discovering and making manifest the mineral wealth of this continent, together with the magnificent fields offered for exploration, have given in America remarkable development and impulse to geological investigation, and the proportion of geologists among our scientific men is probably manifold larger than in any other country. The same may be said of physical geography and of geographical and topographical exploration. But, more than any other art, war has stimulated physical science; and those branches which have been made to contribute most abundantly to military ends are those which have thriven most among military nations. Applied mathematics and the departments of physics useful to the engineer, the topographer and the artillerist have specially flourished in France. An amusing illustration of the relative positions which sciences and arts may occupy under peculiar influences, is furnished by a publisher's book-list, published in Paris monthly. The newly published books are assorted by subjects, and one of the groups uniformly appears as follows: "*Sciences Mathématiques et Militaires:—Astronomie, Arithmetique, Marine, Equitation;*" thus showing how thoroughly the system of classification is arranged from the standpoint of the cavalry-man. National legislation, too, exerts a decided influence, and in our own land by no means a favorable one to the investigator. At this moment the import-duty imposed by law upon apparatus intended exclusively for investigation, in increasing the sum of human knowledge, is nearly three times as great as that upon the same apparatus if imported for purely educational purposes, in disseminating knowledge already attained!

In these remarks, Gentlemen, I have endeavored to lay before you such facts and considerations as may illustrate the position and relations of the follower of science, especially in the United States. What measure of confidence my inferences may deserve, your own experience and judgement must decide; but I am sure you will not doubt my earnest desire so to present them as to wound the sensibilities of no man. I have sought conscientiously to describe the present aspect of scientific culture in our country, neither shrinking from the statement of unwelcome truths, nor refusing admission to the hopeful promises of the future. What that future is to be, rests in great measure with the generation now upon the stage.

The magnificent, the stupendous march of scientific discovery in the recent past, leads to brilliant and almost limitless aspirations for the near future. The range of human insight into the creation has been of late so wondrously expanded at each limit, that we are emboldened to expectations of scientific discovery, which at first seem utterly extravagant. If within a decade we have learned to analyze the incandescent substance of sun and star, comet and nebula,—if we have attained to thermic, electric and acoustic tests, delicate beyond the apparent reach of human perception,—if we have learned the strange relation of meteor and comet, and added even molecular forces to the lists of known cosmical agencies,—if we have traced the laws of thermal refraction within conducting solids, and found out a higher alchemy in the transmutation of forces,—is it too much to expect that a few years more will disclose the subtle relation between conduction and induction; that whatever may correspond to refraction in electricity will be developed; that the source of the phenomena of terrestrial magnetism will be brought to light by the continued study of its laws; that the mystic bond of gravitation may be made less incomprehensible; that, if radiant action without a medium be possible, its mode of operation will be discovered; and that perhaps even the chemical constitution of the luminiferous ether may be analyzed.

In our own country, none of the obstacles to proper scientific development are insurmountable in their character. Serious they are indeed, yet far from discouraging. Amid our hopefulness and faith in the magnificent future which awaits the land we love more than Jews loved Zion, and toward which we look forward with an intenser pride than Athenian or Roman ever felt in the past glories of his country, we are too apt to tinge all the prospect with roseate coloring; and, in the greatness and depth of our confidence, we are tempted to shut our eyes to inauspicious omens. The patriot's duty is not to deny, but to meet and avert, all danger threatening his country; it is to labor for her welfare, not to bask in dreams of her coming glory.

There are already abundant indications of a desire in the community to encourage science. However large a share may have fallen by the wayside, or on stony ground, still much of the liberality already manifested must bear good fruit. And as the fruit ripens and the community receives the resultant benefit, many of the evils already enumerated must infallibly be diminished. That completely vicious circle of administrative policy must sooner or later disappear, by which, in institutions established for noble ends, the aims and objects themselves are lowered for the sake of winning donations for additional endowment. The time cannot fail to arrive when literary, artistic and scientific matters shall at last receive the guidance of literary, artistic and scientific men. Of all intellectual pursuits, our national character seems most inclined to those of science. Would that the prospects of classical culture and refinement were one-half as good as those of scientific progress; for the proper mutual relations once established, these could not fail to reinforce and supplement each the other. In short, we need only the adaptation of our hitherto untried forms of social organization to intellectual as well as material interests,—an adaptation, which the relatively small influence of intellectual pursuits thus far has too long delayed.

The fundamental idea of this Association is the Advancement of Science by promoting intimate relations among those who love and desire to serve her, by gathering from distant regions the various results of scientific study for common discussion and comparison, and by disseminating throughout the country a popular interest in the ennobling pursuits to which we offer our allegiance. The absurdity of casting ridicule upon the Association because it invites to its ranks all lovers of science, whatever their sphere of life, their attainments, or their avocation,—cordially welcoming the contributions and encouraging the attendance of all who avail themselves of this means of furthering the great end,—is only paralleled by that other one, which finds another occasion for ridicule in the policy of confining the decision of purely scientific questions to those who are scientists by vocation. The flippant sneers at scientific institutions of both classes, which not unfrequently meet our eyes, would almost lead us to doubt whether it were desired to confine all scientific culture to a class of Brahmins, or to submit the law of gravitation to a popular vote by majority. In the present critical period of our national development, the need of an organization like this is palpable; and, if only some element of greater stability and of established policy could be introduced (which would seem by no means difficult), its usefulness would be beyond description, reaching to every corner of the continent, and permeating the whole people with its healthful influence.

Our field, Gentlemen of the American Association, lies clearly mapped out before us. Our duties are shrouded in no uncertainty. To disseminate and impress the great truth that God has given us His works to read and His laws to learn; to advance the public estimation of scientific research, not as a means, but as an end,—an end, however, which when honestly pursued never yet failed to bring rich recompense to the community; to encourage and assist all institutions established for the increase of human knowledge; to inculcate respect for learning and reverence for authority; to guide ambition away from the mere accumulation of lucre and toward intellectual aspirations; to deserve the confidence and guide the liberality of good and patriotic men, who would contribute of their own abundance to further the holy cause of science; to protect scientific interests from the greed of those, who would make of them a prey, incited by the lust of money or of power; and by these and all other righteous means to hasten the time when the land of the setting sun shall become the Orient by leading the science of the world, awing the nations rather by her intellectual achievements than by her material power; — these are among the great interests which are committed to our charge.

May we, one and all, so acquit ourselves of these high responsibilities, that coming years shall render a verdict that the republic has received no detriment through negligence or weakness of ours!

PROCEEDINGS

OF THE

SALEM MEETING, 1869.

COMMUNICATIONS.

A. MATHEMATICS, PHYSICS, AND CHEMISTRY.

I. MATHEMATICS.

1. A DEMONSTRATION OF EUCLID'S ASSUMED AXIOM RELATIVE TO PARALLEL LINES. By ALEXANDER C. TWINING, of New Haven, Conn.

THE plain and admitted fact that science feels no defect in its conclusions and experiences, no limitation even of its most subtle and recondite researches in consequence of the acknowledged absence of a link in the rigorous chain of Euclid's demonstrations, does not, apparently, abate the zealous efforts of modern geometry, to have the defect supplied. It may be hard to explain why the human mind should persist in striving after a desideratum which is not felt as an operative necessity, except we recognize a profound conviction of the superiority of pure intellect, upon abstract subjects of thought, to any and all deductions from mere experience. The author of this paper has ventured before,* and ventures now to follow in the wake of the many who have attempted to prove, under the definitions, and by the severe paths of the old geometry, the *noted axiom*—not so accepted however by modern science, nor yet proven to general satisfaction—that *through a given point there can be but one parallel to a given straight line.* In preparing this paper for publication, some substitutions and abbreviations have been made, of which an indistinct intimation was given at the time of its reading. Obviously the chief novelty and principal importance are centred in the resulting proposition, which the *Lemma* here immediately following is made to precede as a mere, although an essential auxiliary, and might be proved yet otherwise.

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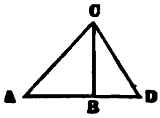
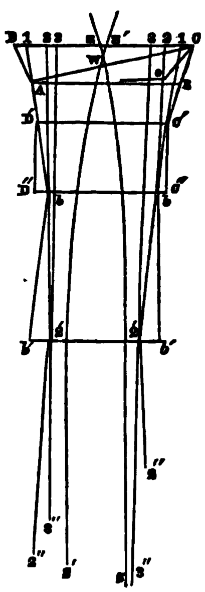
* American Journal of Science and Arts, Vol. I, 2d series, p. 89.

LEMMA.

No triangle can have the sum of its angles greater than two right angles.

If this is proven of right angled triangles, then is it also proven of all triangles; for any triangle whatever, may be divided into two right angled triangles, whose oblique angles together constitute the angles of the given triangle; consequently if it is shown that the oblique angles of neither can together exceed a right angle, it is also shown that the angles of the given triangle cannot exceed two right angles. Accordingly, to prove the above for right angled triangles, let ABC be a triangle, right angled at B; and, if possible, let the two angles at A and C, be together greater than a right angle. Upon AB raise the perpendicular AD equal to BC and join CD. Because the two oblique angles of the triangle exceed a right angle, while the two constituent angles of BAD are only a right angle, it follows that DAC is less than its alternate angle ACB. Reverse AC upon itself, and revolve D down to O, CO must fall within ACB, but, being only equal to BC, cannot intersect AB. Therefore the triangle ACO lies wholly within ABC, and O, or D, exceeds the right angle at B. (Euc. 1, 21.) Then the quadrilateral $ABCD$ has two right angles, and has the angles BCD, CDA, equal, and each greater than a right angle.





Revolve this quadrilateral over into the position $ABC'D'$;

then DAD' is one straight line, and CBC' is also one straight line, and the quadrilateral $CC'D'D$ has its four angles equal to one another, and each greater than a right angle. Revolve it over upon its *terminal side* $D'C'$, into the position $C'C''D''D'$, then $DD'D''$ is a reëntering angle and $CC'C''$ is another equal to it. Draw ${}_1b$ and ${}_1b$ perpendiculars to the *medial line* $D'C'$ at the apices D' and C'. They will meet CD between C and D, and they will also meet $C''D''$ between C'' and D''. Thus there will be formed a new quadrilateral ${}_1bb_1$, having its angles all equal and in excess of the corresponding angles at C, D, D'', C'', because they are exterior to them in the triangles $DD'_1\,D'D''b$, etc. Also, for the like reason, and because D, D'', etc., are obtuse, the lines D'_1, $D'b$, etc., are greater, respectively, than $D'D$, $D'D''$, etc. Revolve the new quadrilateral over on its terminal side bb, into the new position $bb'b'b$. Then ${}_1bb'$, ${}_1bl'$ are reëntering angles whose apices are at the extremities of the medial line bb. Perpendicular to that line, at those extremities and apices, raise the lines $22'$, $22'$; they will meet ${}_{11}$ and $b'b'$ within the points ${}_{1,\,1,}$ and b', b', respectively. And by revolving over the quadrilateral $222'2'$ upon its terminal $2'2'$, this last will become a third medial line whose extremities are the apices of a third pair of reëntering angles $22'2'$, from which a third pair of perpendiculars $2'3$, may be raised, cutting the fixed terminal side, DC, in the points 3, 3, and making 33, less than 22, or than its equal, $2'2'$. And this course of construction, it is evident, may be continued at pleasure, so long as there remains a medial line at whose extremities new perpendiculars may be raised and produced backwards, to cut both DC and its corresponding and opposite terminal side; that is to say, so long as the successive segments $C1$, $C2$, $C3$, etc., have not increased to a length, as CZ, which shall have either met its opposite and equal DZ', at the middle point between D and C, or the two shall have passed each other as seen in the figure. Now these segments cannot but so increase as to meet in the middle of DC or to cross; for the interior angles at 1, 2, 3, etc., are less than right angles, and consequently $C1$ exceeds a perpendicular from C to C' 1, also 12 exceeds a perpendicular from 1 to $b2$, and so on successively. Moreover these perpendiculars themselves successively increase in magnitude, because they subtend, successively, larger angles $CC'1$, $1b2$, $22'3$, etc., and from the extremities of successively longer sides $C'1$, $b2$, $2'3$, etc., opposite the respective right angles, as is shown by the construction.* Therefore neither $C11$, 22, 3, nor any succeeding increment of CZ or DZ' can be so small as the perpendicular from C to $C'1$. Let SZ, $S'Z'$ be the two equal perpendiculars which are the first to meet or pass each other. These are drawn, by construction, from the extremities of a medial line. Thus, it follows, there can be drawn from a point, W, of their meeting and crossing, two perpendiculars to one and the same line, which is impossible. Therefore it is absurd to suppose *that any right angled triangle, or any triangle whatever, has the sum of its angles greater than two right angles;* which was the point to be proved.

PROPOSITION.

Through a given point there can be but one parallel to a given straight line.

Let AB be the given straight line, and C a given point. Through C draw CF' at right angles to CA, a perpendicular to the given line. Then CF' is the only straight line through C, which cannot meet AB.

DEMONSTRATION.

Let there be any straight line, as CO, drawn through C, within the right angle at that point, and from some point G therein let GF be a perpendicular to CF'. Bisect CF in f, and raise the perpendicular fI, meeting CO in I. In FG, produced if necessary, take FK double fI; join and produce IK, and draw IH to the bisecting point between F and K. Because it has been shown that the right angled triangle $Cf1$ cannot have its three angles together greater than two right angles they must either be together equal to two right angles, or together less than two. If the latter, then will *FG* be greater than *FK*; for let *f* and *H* be joined, and obviously the triangle *fFH*, by construction, is equal and similar to *CfI*, and therefore has the sum of its angles less than two right angles. But the triangle *fIH* cannot have more than two right angles, consequently the two triangles *fFH*, *fIH*, which together constitute the quadrilateral *fFHI*, cannot have so much as four right angles, and therefore the two angles *fIH*, *FHI*, are together less than two right angles. But from the equality of the perpendiculars *fI*, *FH*, the last named angles are equal to one another, and therefore each is less than a right angle. Reverse *IH* upon itself, and revolve over *HG* into the position *Ig*. Then, because *HIg*=*IHG* exceeds a right angle, it will lie out of *HIf*, which has been proved less; and, because *fHG*, *GIf*, are the supplements, respectively, of the equal angles *fHF*, *CIf*, they are equal to one another; and *fHG* less *IHG*, or the angle *fHI*, is less than *GIf* diminished by *HIf*, or in other words, than the angle *HIG*=*IHg*. Consequently *IHg* lies outside of *IHf*, and the apex *g* lies outside of the triangle *IfH*, and *Ig*=*HG*, is greater than *If*, or than its equal by construction, *HK*; because, if *f* and *g* were joined, the angle *Ifg* would be greater and the angle *Igf* less than a right angle. But also the angle *IgH*=*IGH* is less than *IfH*; by which it appears that *IGH*+*FfH*=*CGF*+*FCG* is less than the two angles at *f* within the quadrilateral; that is, they are less than a right angle. Consequently it is proven that *if the angles of CfI are together less than two right angles, the same*

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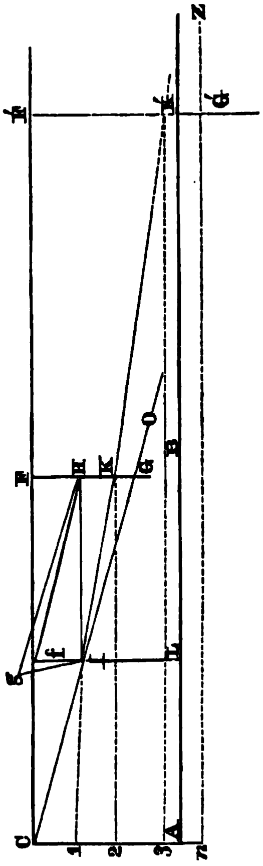
* For the reëntering angles, successively diminish, and therefore the half difference between each, and two right angles increases; also $C'1 > C'C$, and much more, $b1 > C'C$. In like manner $2'2 > b1$ and so on. And to suppose that the same or a less perpendicular can subtend the same given angle (and much more a greater angle) at a greater distance from the angular point, may easily be seen to involve the absurdity that two perpendiculars to the same line may be drawn from that angular point.



is true also of the angles of CFG*; and also that* HG *is greater than* $HK=fI$. From I drop IL a perpendicular to AB, then, the same things being given, the angle LIG, must lie within the angle LIK. And yet more, *if necessary or desired*, let the perpendicular $F'G'$ be raised at the distance $CF'=2CF$, and $F'K'$ be taken twice FK, then the same things given, and the line IK' being drawn, it may in like manner be shown that if CG produced will meet the perpendicular in G', $F'G'$ must be greater than twice FG, and much more be greater than twice FK, and that LIG' would lie within the angle LIK'; but if CG produced cannot meet $F'K'$ produced, then much more must the angle LIO lie within LIK'. And still again, if another perpendicular $F''K''$ be supposed, the double of $F'K'$, and raised at a supposed distance CF'' twice that of CF', and meeting CI produced in G'', then will $F''G''$ be more than twice $F'G'$, and so on indefinitely, and the same things may be proven as before.

It follows from all the above that if the line CI produced passes through K, then the three angles of CfI are not less than two right angles. But they cannot be greater and must therefore equal two right angles. And, in fact, it will readily be seen, *ex converso*, that if the angles of CfI are equal to two right angles, then CI produced must pass though K, and also through K', K'', etc., indefinitely, and must meet the line AB. To prove this join fH, then the triangle fFH by its construction is every way equal and similar to CfI, and its angle at H being complementary to its angle at f is equal to the angle HfI, which is complementary to the same,—wherefore (Euc. 1. 4.) the triangles fHF, HfI, have their third sides equal to each other and to Cf, and also the angle at I equal to the right angle at F, and also the two angles at H, or FHI, a right angle; and IF is a rectangle. Consequently, also, the two triangles IHK, CfI, having the angles at H and f right angles, and the sides HK and fI equal by construction, and the sides IH, Cf equal, are equal and similar triangles — wherefore the three angles at I together make two right angles, and CIK is one straight line, and the angles of CFK are together two right angles. And in like manner may the same be proven of the triangle $CF'K'$, and of the supposed triangle $CF''K''$, and so on indefinitely. Take in CA produced the distances $C1$, $C2$, $C3$, equal, respectively to fI, FK, $F'K'$ and so on, — each being double of the preceding, till Cn is found a greater than CA, and join $I1$, $K2$, $K'3$, and so on. In the same manner as IF was proven a rectangle may $f1$ be proven to be the same, and also, consecutively, $F2$, $F'3$, and so on indefinitely for successive perpendiculars to DA, each of which is met by CI produced, till finally the perpendicular Zn is proven to be met, as in Z, by the same. But AB cannot meet Zn, for if so it would form with it and the segment An a triangle whose angles were together greater than the two right angles. Consequently CI produced will meet AB. Hence it has been demonstrated that *if CI produced passes through K it will meet AB*; and it has before been shown that *if it does not pass through K* it will pass at some angle LIG within LIK, and consequently *much more will it meet AB.* Therefore it will meet AB whether it does pass or does not pass through K. But CI or CO is any line whatever that makes an inner angle at C with CF'. And if that inner angle is made on the opposite side from O, the line must, if produced, meet AB on that side, as already proved for the side towards O. But CF' cannot meet on either side; for, if so meeting, it would form with AB and AC a triangle having its angles together in excess of two right angles, which is absurd. Consequently CF', which cannot itself meet AB, is the only line through C that cannot so meet:— which was to be demonstrated.

2. On the Construction of three Maps of Europe, France, and North America, in the Gnomonic Projection, with a view to the Distribution of Mineral Wealth and the study of the Earth's Figure. By Felix Foucou, Madison, Wisc.

I have the honor to present to the American Association the formula and calculations relating to a set of maps in the gnomonic projection, in the construction of which I have been engaged about four years. In such a system of projection, the surface of a country is developed upon a plane, tangent to the terrestrial spheroid at the centre of the said country; all the points of the map are determined by the intersection of that plane with the radii of the sphere. The result of it is that every grand circle is represented as a straight line. So the eye is able to discover at a glance, whether the line which connects several points of geographical or geological importance, is or is not a grand circle of the earth. The practical superiority of these maps over all others now used lies in the fact, that on the latter ones every grand circle is represented by a curve line, which can be determined only by a graphical construction, or a series of calculus operations which involve a loss of time, and sometimes chances of mistake.

Finally, the practical value of the gnomonic projection is to guide more surely the mining operations and the geographical studies, as it is well ascertained that many grand circles of the earth are, altogether, the lines of dislocation of the earth's crust and the belt of mineral wealth of similar origin. Such a relation is fully illustrated, both in Europe and America, by recent discoveries of metallic mines and mineral springs, and by the close study of the main features of the two continents. However it must be understood that I engaged myself in the construction of gnomonic maps, not in order to advocate any theory of the figure of the earth, but to collect facts and compare them more easily than it is possible to do it with the actual systems of projection; these systems are excellent for several purposes, and we must keep them; but they require a complementary one, which is the gnomonic or radiated system.

A map of Europe, about forty square feet large, is quite finished since January last, and will be engraved in order to represent the geological structure of that continent. The original sheet is in Paris (France), and will be brought to America as soon as the work of engraving is completed.

At the same time, my assistant is engaged in the drawing of a special map of France, measuring about ten square feet, and a preliminary map of North America, of about the same size.

The formulas which have been used are new and simple; they require but the knowledge of elementary mathematics, and are calculable by logarithms. The calculations are to determine the meridians by their distance from an axis, and the parallels by their intersections with each meridian. The formula relating to the meridians is

$$d = R \text{ tang } l \cos L'$$

R being the radius of the sphere, l the longitude of the meridian, L' the latitude of the centre of the map, which centre is the point of tangence of the sphere with the plane of projection; d is the distance between the same centre and the point where the meridian intersects the axes of the map, which axis is the meridian of the centre.

The formula relating to the parallels is

$$x = \frac{R \cos \lambda \cos \delta \text{ tang } l}{\sin (\lambda + \Psi)}$$

R being the radius of the sphere, l the longitude of the meridian, λ the latitude of the parallel, δ and Ψ two auxiliary angles, and x the distance between the axis of the map and the intersection of each meridian with each parallel.

The geographical drawing has been, and is still, actually performed in Paris, with the prospect of being subsequently pursued in the United States, and I will not fail to let the *American Association* know the progress of the work and its practical applications to the art of Mining and the Science of Geography.

II. MECHANICS.

1. The Laws of the Deflection of Beams exposed to a Transverse Strain, tested by Experiment. By W. A. Norton of New Haven, Conn.

I propose, on the present occasion, to communicate the principal results of a series of experiments made with an apparatus which I devised for the purpose of testing the theoretical laws of the deflection of beams exposed to a transverse strain.

[The apparatus was described in detail with the aid of several large diagrams. The following description will suffice to give an accurate idea of its essential features.]

It may be regarded as consisting of three different portions, viz.: (1) that which supports the stick to be experimented on; (2) that which applies and measures the strain; (3) that which measures the deflection produced. The supporting apparatus consists of two skeleton iron tables, each of which is a rectangular wrought iron frame, two and three-fourths feet long by two feet broad, resting at the four corners upon cast-iron legs two and a half feet high. The longitudinal bars of this frame are one inch broad by two inches deep. These tables are placed lengthwise on the same line, say a north and south line, and one foot four and a half inches apart. Each of them supports a transverse sliding frame composed of two wrought iron bars, one inch by two inches, placed four inches apart, and formed at the ends into two sliding saddle pieces that rest upon the longitudinal bars of the table-frame. These sliding frames can be set at any distance apart, from two feet to six feet. Upon each of them rests an iron plate five-eighths of an inch thick, and fitted by grooves to the two iron bars, so as to be movable in the direction of their length, or crosswise to the lengths of the tables. Upon these plates rest two cast-iron supports, each consisting of an upright pillar, one and one-eighth inches square in cross section and twelve inches high, connected at the bottom with a plate that is supported by four leveling screws upon the sliding plates just described, and at the top with a plate five inches long (crosswise to the table-frames), two and one-eighth inches broad and five-eighths of an inch thick. The nearer edges of the top plates of these upright supports are beveled off, so as bring them immediately over the pillars. The stick experimented on rests immediately on these iron plates, and its effective length is the distance between their nearer edges.

The mechanical contrivance for applying the strain to the stick, like the supporting apparatus just described, is wholly made of iron, and consists of an upright screw, turning by means of female screws in two horizontal plates fastened at their four corners to upright columns. These columns are firmly connected with an iron bed plate, which is placed between the table supports above described and securely fastened to the floor-joists by long screw-bolts. The screw-head is connected by intermediate pieces with an iron stirrup that rests crosswise upon the stick. There is a special arrangement, which cannot well be described here, by which these intermediate pieces are made to move in a truly vertical direction, and not partake, in any degree, of the revolving motion of the screw. One of the intermediate pieces referred to, is a Fairbank's Spring Dynamometer (essentially the same as Regnier's). The circular dial-plate reads from one pound to one thousand pounds. By means of the screw a power of one thousand pounds can be applied to the stick; but in the experiments the strain was in no instance carried higher than five hundred pounds.

The apparatus for measuring the deflection produced, consists of a brass lever of two arms, each five inches long, one end of which is depressed by the middle of the bent stick, and the equal rise of the other is measured by a micrometer-screw. This micrometer-screw reads to one ten-thousandth of an inch. The lever is placed crosswise to the length of the stick and opposite its middle. It passes through a vertical slot in the iron stirrup that rests upon the middle of the stick, and presses by a blunt steel knob against the under side, the farther end of the lever being made slightly heavier than the other, so as to secure a moderate pressure. The arrangement for supporting the lever consists of a wooden strip six and a half feet long, two and three-eighths inches deep, and one-half inch thick, stiffened along the top by a strip of brass. This is secured to the pillars of the two upright supports, by clamping pieces, which firmly hold it at a distance of five inches from the centres of the pillars and parallel to the length of the stick. Upon this supporting strip rests a sliding saddle-piece, having a small flat plate on the top, and adjustable by horizontal screws that pass through its vertical side plates and press against the vertical sides of the wooden strip. Upon the top plate of this saddle-piece rests, by means of four leveling screws, another small plate, upon which the knife-edge of the lever immediately rests. From the vertical side-plate of the saddle-piece that is farthest from the stick, extends a small horizontal bar, six inches long. This lies directly under the farther half of the lever. Near its farther end the micrometer-screw passes through it from below upward, and touches the under side of the lever, at a distance of five inches from the knife-edge support. The contact of its rounded point with the lever is observed with a microscope. The screw-head, adapted to the lower end of the screw, is two inches in diameter. Its outer vertical edge is silvered, and graduated to read to thousandths of an inch; but a small vertical wire fastened to the bar above it, past which the screw-head moves, subdivides the smallest space on the graduation, so as to make it possible to read to the one ten-thousandth of an inch. Since the knife-edge of the lever is at the same distance from the point of contact with the upper end of the micrometer-screw and from that with the middle of the under side of the stick, the micrometer readings are the linear deflections of the middle of the stick. It will be observed that the depressions of the knob of the lever under the middle of the stick, will be the actual deflections; since the support of the fulcrum of the lever is firmly connected with the upright supports of the stick, and will partake of any depression that they may experience from any settling of the apparatus under the action of the force that produces the deflection. It may be remarked here that it was ascertained, by an independent set of experiments, that the actual depression of the apparatus was very small; only from two to three-thousandths of an inch for every one hundred pounds of pressure.

The manner of conducting the experiments will be readily understood. The inner edges of the top surfaces of the upright supports upon which the stick is to rest, are set at a distance apart equal to the proposed effective length of the stick; either two feet, four feet, or six feet. These surfaces are carefully leveled and adjusted to the same horizontal plane. The lower plates of the upright supports are firmly clamped to the sliding frames on which they rest, by portable clamps. The stick is then put in its place, the iron stirrup placed crosswise upon its middle, and connected by a sliding bolt and key with the upper end of the closed spring of the dynanometer. The apparatus for measuring the deflections is also leveled and adjusted. The screw is then slowly turned until the index of the dynanometer indicates one hundred pounds, two hundred pounds, or any other force of pressure it is proposed to apply, and the reading of the micrometer-screw indicates the linear deflection of the middle of the stick produced by the pressure applied.

The experiments were made upon white pine sticks of various lengths, from two feet to six feet, and various breadths and depths, from one inch to four inches. The results are derived from the means of a large number of experiments. As an additional test the experiments were repeated upon a second set of sticks.

The received theoretical formula for the deflection of beams of a rectangular cross section of uniform dimensions, is $f = m\frac{Pl^3}{Ebd^3}$ in which m is a constant, P the power applied, E the modulus of elasticity, l the length, b the breadth, and d the depth of the stick. For the case of a beam resting freely on two supports and loaded in the middle, to which the experiments were entirely confined, this becomes $f = \frac{Pl^3}{4Ebd^3}$. If this formula be correct, then the following laws must be true.

(1). The deflection is directly proportional to the pressure.

(2). It is inversely proportional to the breadth.

(3). It is inversely proportional to the cube of the depth.

(4). It is directly proportional to the cube of the length.

We will now compare each of these laws with the experimental results obtained.

First Law. The deflection is directly proportional to the pressure. The following table contains a few of the results that serve to test this law. The first three columns give the lengths, breadths, and depths of the sticks, and the last column gives the differences between the deflections produced by the two pressures given in the column headed Difference of Pressures.

The deflections for the first one hundred pounds of pressure are not included, for the reason that there is more liability to error in observing the absolute deflection than in observing the increments of deflection produced by each one hundred pounds of augmented pressure, starting from a pressure of one hundred pounds. The actual results for the first one hundred pounds are given, for comparison, at the bottom of the table.

TABLE I.

Sticks.			Diff. of Pressures.	Diff. of Deflections.
Length.	Breadth.	Depth.		
				in.
2 ft.	4 in.	2 in.	100 lbs. to 200 lbs.	0.0114
"	"	"	200 " " 300 "	0.0102
"	"	"	300 " " 400 "	0.0090
"	"	"	400 " " 500 "	0.0090
4 ft.	2 in.	3 in.	100 " " 200 "	0.0459
"	"	"	200 " " 300 "	0.0460
2 ft.	3 in.	2 in.	100 " " 200 "	0.0159
"	"	"	200 " " 300 "	0.0135
"	"	"	300 " " 400 "	0.0127
2 ft.	2 in.	3 in.	100 " " 200 "	0.0068
"	"	"	200 " " 300 "	0.0084
"	"	"	300 " " 400 "	0.0080
				in.
2 ft.	4 in.	2 in.	0 lbs. to 100 lbs.	0.0119
4 "	2 "	3 "	" " "	0.0477
2 "	3 "	2 "	" " "	0.0164
2 "	2 "	3 "	" " "	0.0092

The following table gives the deflections for one hundred pounds, two hundred pounds, three hundred pounds, &c., pressure:

TABLE II.

Sticks.			Pressures.	Deflections.
Length.	Breadth.	Depth.		in.
2 ft.	4 in.	2 in.	100 lbs.	0.0119
"	"	"	200 "	0.0233
"	"	"	300 "	0.0335
"	"	"	400 "	0.0426
"	"	"	500 "	0.0516
4 ft.	2 in.	3 in.	100 "	0.0477
"	"	"	200 "	0.0936
"	"	"	300 "	0.1396
2 ft.	3 in.	2 in.	100 "	0.0164
"	"	"	200 "	0.0323
"	"	"	300 "	0.0458
"	"	"	400 "	0.0585
2 ft.	2 in.	3 in.	100 "	0.0092
"	"	"	200 "	0.0181
"	"	"	300 "	0.0264
"	"	"	400 "	0.0344

It appears from the results given in tables I. and II, that the deflection is approximately proportional to the pressure; but strictly speaking increases according to a less rapid law. The probable explanation of this descrepancy between theory and fact, is that as the force of pressure increases the neutral axis of the cross section of the stick shifts its position, and its distance from the centre of gravity of the cross section augments as the pressure becomes greater. From this cause the moment of the resistance to flexure increases indirectly with the pressure, at the same time that it increases directly from the augmented strains of the fibres. The increased moment of resistance to flexure resulting from this shifting of the neutral axis, should be attended with a diminished increment of deflection for the same increment of pressure.

Second Law. The deflection is inversely proportional to the breadth. Table III. will serve to test this.

TABLE III.

Sticks.			Obs. Deflection for 100 lbs.	Cal. Deflection for 100 lbs.	Difference.	Ratios of Error.
Length.	Br'dth.	Depth.				
			in.	in.	in.	
2 ft.	1 in.	2 in.	0.0423	0.0423		
"	2 "	"	0.0195	0.0211	+0.0016	1-12
"	3 "	"	0.0147	0.0141	−0.0006	1-24
"	4 "	"	0.0106	0.0106	0.0000	
4 ft.	1 "	"	0.2858	0.2858		
"	2 "	"	0.1200	0.1429	+0.0229	1-5
"	3 "	"	0.0983	0.0952	−0.0031	1-32
"	4 "	"	0.0624	0.0714	+0.0090	1-7

The numbers in the column of calculated deflections are obtained by assuming the observed deflection for the smallest breadth (one inch), and computing the deflection for the other breadths on the supposition that it is inversely proportional to the breadth. The last column gives the ratios of the differences between the observed and calculated deflections, given in the preceding column, to the observed deflections. The observed deflections answer to an increase of pressure from one hundred pounds to two hundred pounds, or two hundred pounds to three hundred pounds. It will be seen that the errors are some plus and others minus, and that the ratios of error are small fractions. They are, however, too great to be attributed entirely to errors of observation; but not greater than may reasonably be ascribed to differences in the moduli of elasticity of the different sticks, and to the greater shifting of the neutral axis in the case of the sticks most strained, in connection with possible errors of observation.

Third Law. The deflection is inversely proportional to the cube of the depth.

It soon became evident, in the course of the experiments, that this law could not be regarded as even approximately true, except in the cases of sticks, or beams, whose length bore a high proportion to their depth. The following comparisons of observed with calculated deflections will show that it fails in the case of sticks two feet in length.

TABLE IV.

Sticks.			Ratios of bd^3	Obs. Deflec.	Cal. Deflec.	Diff.	Ratios of Error.
Length.	Br'dth.	Depth.					
				in.	in.	in.	
2 ft.	2 in.	1 in.		0.1414			
2 "	1 "	2 "	1 to 4	0,0423	0.0353	—0.0070	1-6
2 "	3 "	2 "		0.0147			
2 "	2 "	3 "	1 to 2¼	0.0084	0.0065	—0.0019	1-4.4

TABLE V.

Sticks.			Ratios of d^3	Obs. Deflec.	Cal. Deflec.	Diff.	Ratios of Error.
Length.	Br'dth.	Depth.					
				in.	in.		
2 ft.	2 in.	1 in.		0.1414			
"	"	2 "	1 to 8	0.0195	0.0177	—0.0018	1-11
"	"	3 "	1 to 27	0.0084	0.0052	—0.0032	1-2.6

The calculated are all less than the observed deflections. The same is true when sticks of greater length than two feet are taken, but the errors are smaller in proportion as the length is greater. It appears, therefore, that the deflection decreases according to a less rapid law than the inverse cube of the depth.

Fourth Law. The deflection is directly proportional to the cube of the length.

The experiments show that this law fails, as well as the third.

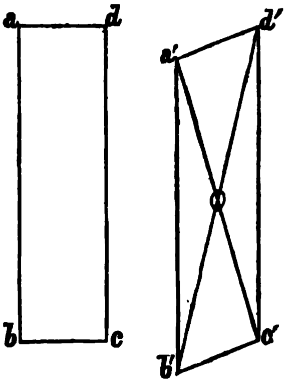
TABLE VI.

Sticks.			Ratios of l^3	Obs. Deflec.	Cal. Deflec.	Diff.	Ratios of Error.
Length.	Br'dth.	Depth.					
				in.	in.	in.	
2 ft.	2 in.	2 in.		0.0195			
4 "	2 "	2 "	1 to 8	0.1200	0.1560	+0.0360	1-3.33
2 "	2 "	3 "		0.0084			
4 "	2 "	3 "	1 to 8	0.0460	0.0672	+0.0212	1-2
2 "	3 "	2 "		0.0147			
4 "	3 "	2 "	1 to 8	0.0983	0.1176	+0.0193	1-5
2 "	4 "	2 "		0.0106			
4 "	4 "	2 "	1 to 8	0.0624	0.0848	+0.0224	1-2.8

We may conclude, from these results, that the deflection increases according to a less rapid law than the cube of the length of the stick. We have already seen that it decreases in a less rapid proportion than the inverse cube of the depth. It follows, therefore, that the true formula for the deflection probably contains at least one additional term, which varies less rapidly than as the cube of the length directly and the cube of the depth inversely; or in other words, contains l in the numerator, and d in the denominator, each raised to a lower power than the cube. Now, if we consider attentively the changes that must occur in the relative positions of the molecules within a stick or beam, when it is subjected to a cross strain, we may perceive that a cause of deflection exists which has hitherto been disregarded, or deemed too insignificant in its effects to be taken into account.

It is plain that when a stick, or beam, of a uniform rectangular cross section, resting on two supports, is loaded at its middle, a vertical force equal to one half the weight is transmitted to each support, by the slipping of each vertical section, or lamina, upon the next, until a vertical force of resistance is called into play equal to half the weight. As each section must transmit this same force to the next, the slipping of one section upon another must be the same from the middle to the end. The section at the middle will be directly depressed, from this cause, by an amount equal to the sum of all these displacements that occur between the middle and the end, or to any one displacement multiplied by the number of sections, or indefinitely thin laminæ, in this interval. This depression should, then, be directly proportional to the half-length, or length of the stick. If we compare sticks of the same length but different cross sections, the number of fibres that are subjected to this cross strain, or the number of material points in each cross section whose vertical resistance will be called into operation by the slipping of this section upon the next, will be proportional to the area of the cross section, and hence the amount of the relative sliding displacement will be inversely proportional to this area. It will be seen, then, that the sinking, or linear deflection of the middle of the beam, thus directly resulting from the slipping of contiguous vertical sections, may be represented by the expression $c \frac{Pl}{bd}$; in which P is the load, l the length, b the breadth, and d the depth of the beam, and C a constant that must be determined by experiment.

The theoretical deflection given by the formula which has been under discussion, is due to longitudinal strains on the fibres, indirectly resulting from the same slipping of contiguous sections. If *ab* and *cd* represent two vertical cross sections, indefinitely near to each other, of which *ab* is nearest the middle of the beam, the transmission of the action of the half-weight will cause *ab* to slip relatively to *cd* until a vertical resisting force comes into operation equal to the half-weight; and the rectangle *abcd* will take the form of the oblique parallelogram, *a′b′c′d′*. The diagonal *ac* will therefore be shortened, and *bd* lengthened. Accordingly a strain of compression



will come into operation along $a'c'$, and a strain of extension along $b'd'$. The reactions to these strains will take place, along $a'c'$ from the middle o toward a', and from o toward c', and along $b'd'$ from b toward o, and from d' toward o. As a consequence the points a', and d', will be urged by equal forces toward the left, or toward the middle of the beam, and the points b', c', by the same forces, toward the right. The sum of the first two forces will then be a longitudinal strain of compression on the upper fibre, and the sum of the last two an equal strain of extension on the lower fibre. It will be observed that the strains here considered as confined to the upper and lower fibres, are actually distributed over all the fibres above and below the middle fibre of the beam.

The conclusions here arrived at with regard to one indefinitely small rectangle *abcd*, will be equally true of any other that may be considered between the middle and end of the beam; and the same longitudinal strains will be developed by the slipping of contiguous sections, in each rectangle. The entire longitudinal strains on the fibres, at the middle, will then be the sum of the individual strains developed in all the rectangles of the half length of the beam. The ordinary equation of equilibrium of a beam may be readily made out from the present point of view; but we have now only to consider the matter of deflection. It will be seen that the movements, to the left and right, of the angular points of the parallelogram $a'b'c'd'$, that have been signalized, will be attended with a turning of the whole parallelogram from right to left around its centre o. The direct tendency to rotation will be the same for each parallelogram of the half length of the beam, but owing to the propagation of the longitudinal strains on the fibres developed at each parallelogram, from the end to the middle, the actual compressions and elongations will be greatest at the middle, and the actual rotation of the parallelogram there will be the greatest. The deflection consequent upon the elongations and compressions of the fibres, is the joint result of the rotary movements of all the parallelograms in the half length of the beam; and it is represented by the formula which has been under discussion.

It would seem, then, that the true theory of deflection con ducts to the following formula, in the special case of a beam resting on two supports and loaded in the middle.

$$f=c\frac{Pl}{bd}+\frac{Pl^3}{4Ebd^3}$$

Let us now proceed to compare this formula with our experimental results. For this purpose we will determine the values of the two constants *C* and *E* for each individual stick, and compare the several values obtained. If the formula be correct, the different sticks all in precisely the same mechanical condition, and the experiments perfectly accurate, we should get the same values for these constants in the case of each stick. But the experiments are liable to more or less of error, and the sticks may differ materially from one another in their mechanical condition; and even where they do not, as the actual deflections experienced are so different with sticks of different dimensions, any changes in the values of the constants that may result from the shifting of the position of the neutral axis, under the operation of the strains, should differ more or less. The derived values of the constants may therefore differ among themselves, within certain limits, without leading us to conclude that the formula is probably at fault.

The following table contains the values of *C* and *E*, calculated from the deflections due to one hundred pounds, for two sets of sticks of the same dimensions. They were all over four feet in actual length, but in the experiments the effective lengths taken were either two feet or four feet. The values of *E* and *C* were obtained, in some instances, by taking the deflections for the same breadth and depth but different lengths (either two feet or four feet), and in other instances by taking the deflections for the same length but different breadths and depths. The results of two sets of calculations are given in the table. In the one the deflections answering to the least and greatest strains are taken, and the deflection due to one hundred pounds computed from the difference of these by simple proportion; in the other the same is obtained by taking the deflections answering to strains, or pressures, intermediate between the extreme strains.

TABLE VII.

Sticks.			Diff. of Extreme Pressures.		Diff. of Intermediate Pressures.	
Set No. 1.			*E.*	*C.*	*E.*	*C.*
l.	*b.*	*d.*				
ft. ft. 2, or 4	in. in. 2	in. in. 1	1,359,500 lbs.	0.0000108	1,308,430 lbs.	0.0000082
2	2, or 3	3, or 2	1,566,809 "	0.0000100	1,579,960 "	0.0000095
4	2, or 3	3, or 2	1,584,820 "	0.0000087	1,560,800 "	0.0000078
2, or 4	4	2	1,552,000 "	0.0000140	1,501,200 "	0.0000127
2, or 4	2	2	1,481,800 "	0.0000108	1,423,600 "	0.0000084
Means, ...			1,508,986 "	0.0000108	1,474,798 "	0.0000093
Set No. 2.						
ft. ft. 2, or 4	in. 3	in. 2	1,277,729 lbs.	0.0000084	1,254,000 lbs.	0.0000080
2, or 4	2	3	1,295,984 "	0.0000069	1,315,000 "	0.0000068
2, or 4	4	2	1,558,900 "	0.0000110	1,542,860 "	0.0000107
2, or 4	2	2	1,561,822 "	0.0000084	1,600,000 "	0.0000100
Means, ...			1,423,609 "	0.0000092	1,427,965 "	0.0000094

The general formula applicable to white pine sticks of the general quality used in these experiments, will be obtained by taking the mean of the several values of E and C given in the above table. To test the theoretical formula we have obtained we will take the mean values of E and C, for the second set of sticks, given at the bottom of the fourth and fifth columns, viz.: $E = 1{,}427{,}965$ pounds, and $c = 0.0000094$. We thus have

$$f = 0.0000094 \frac{Pl}{bd} + \frac{Pl^3}{5{,}711{,}860 \times bd^3}$$

or, taking $P = 100$ lbs.,

$$f = 0.00094 \frac{l}{bd} + \frac{l^3}{57{,}118.6 \times bd^3}$$

The following table contains the values of f calculated by this formula, and the results of a comparison of the calculated values with the deflections observed.

TABLE VIII.

Sticks.			Cal. Values of *f*.	Obs. Deflec.	Difference.	Ratios of Error.
l.	*b*.	*d*.				
			in.	in.	in.	
4 ft.	3 in.	2 in.	0.0882	0.0983	—0.0101	1-9.7
2 "	3 "	2 "	0.0140	0.0147	—0.0007	1-21
4 "	2 "	3 "	0.0434	0.0460	—0.0026	1-18
2 "	2 "	3 "	0.0082	0.0084	—0.0002	1-42
4 "	4 "	2 "	0.0661	0.0624	+0.0037	1-17
2 "	4 "	2 "	0.0104	0.0090	+0.0014	1-6.4
4 "	2 "	2 "	0.1323	0.1200	+0.0123	1-9.8
2 "	2 "	2 "	0.0208	0.0195	+0.0013	1-15

The comparative accuracy of the old and new formulas, will be seen on comparing the ratios of error in tables IV, V, and VI, and table VIII. It should be added that the results given in table IV, are from calculations made in each instance on sticks which are identically the same, whereas those in table VIII, are affected with the errors resulting from the fact that the values of *E* and *C* are the mean values obtained from a number of different sticks, which may differ more or less in their mechanical condition. If we take the average values of these constants given in the table for the stick three inches by two inches in cross section, and obtained by taking the deflections answering to the lengths, two feet and four feet, the formula thus obtained gives, for these transverse dimensions and the lengths, two feet and four feet, respectively, four results, the ratios of error of which lie between one fifteen-hundredth and one one-hundred and twentieth.

Let us compare the values of the first and second terms of the formula. This is done in table IX. The values of *E* and *C* taken in the formula, are the individual values for each stick given in the second and third columns of table VII.

TABLE IX.

Sticks.			First Term.	Second Term.	Ratio.	Sum.
l.	*b.*	*d.*	in.	in.		in.
4 ft.	3 in.	2 in.	0.00693	0.08952	1-12	0.0964
"	2 "	3 "	0.00692	0.03979	1-5.7	0.0467
"	4 "	2 "	0.00658	0.0554	1-8	0.0620
"	2 "	2 "	0.01000	0.1106	1-11	0.1206
"	1 "	2 "	0.01776	0.2681	1-15	0.2858
2	3 "	2 "	0.00346	0.01119	1-3.2	0.0146
"	2 "	3 "	0.00346	0.00497	1-1.4	0.0084
"	4 "	2 "	0.00328	0.00698	1-2	0.0103
"	2 "	2 "	0.00500	0.01383	1-2.8	0.0188
"	2 "	1 "	0.00990	0.13150	1-13	0.1414
"	1 "	2 "	0.00990	0.03301	1-3.3	0.0429

It will be observed that the value of the first term is in general comparatively larger for the length of two feet, than for that of four feet; and in two instances is as large as one-half the second term.

If now we divide the first term by the second, we obtain as the general expression of their ratio, $4\,E\,C\frac{d^2}{l^2}$; from which we see that it is proportional to $(\frac{d}{l})^2$. When $\frac{l}{d}=\sqrt{4\,E\,C}$, $4\,E\,C\frac{d^2}{l^2}$ becomes equal to unity, and the first term equal to the second. When $\frac{l}{d}$ has a less value than this, the first term is greater than the second. Taking the mean values of E and C, given in the last two columns of table VII, for the first set of sticks, we have $\sqrt{4\,E\,C}=7.41$. The mean values given in the same columns for the second set of sticks, give $\sqrt{4\,E\,C}=$ 7.33. If therefore the length of a white pine stick be less than about seven and one-third times the depth, the deflection from the cause heretofore neglected becomes greater than from the cause to which the whole deflection has hitherto been ascribed. When the length and depth are equal, it is nearly fifty-five times greater; from which it appears that in this case the deflection directly due to the slipping of contiguous vertical laminæ, so greatly preponderates over that indirectly resulting from the same by reason of the longitudinal strains communicated to the fibres, that the latter is comparatively inappreciable.

It will be seen, from the general expression for the ratio of the two terms, above obtained, that the formula for the deflection may take the following form:

$$f=\frac{Pl^3}{4\,Ebd^3}\left(4\,EC\frac{d^2}{l^2}+1\right).$$

I have made, with the same apparatus, a series of experiments on the degree of set, or residual deflection, communicated to sticks by varied strains, and under various circumstances, and obtained interesting and valuable results. The discussion of these experiments is reserved for another occasion.

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2. SUGGESTIONS ON THE THEORY OF THE COMPOSITION OF FORCES. By F. W. BARDWELL, of Washington, D. C.

(ABSTRACT.)

THAT velocity is proportional to the force causing it, we can only know from experience, but the principle of the composition of velocities, known as the parallelogram of velocities, is obvious from geometrical considerations, and is entirely independent of any relation between velocity and the force causing it. But if force is proportional to velocity, then the principle of the parallelogram of forces necessarily follows. If force is not proportional to velocity, then, as necessarily, the principle of the parallelogram of forces fails to hold.

The logical order of the exposition of the composition of forces then seems to be: — First, to establish from geometrical considerations the parallelogram of velocities. — Secondly, to show that in all the varied combinations of forces, acting both in nature and under the control of man, the results verify the

assumption that force is proportional to velocity, and that this principle may be accepted.—Thirdly, that the principle of the parallelogram of forces necessarily results from the two previous.

LaPlace, in his *Mecanique Celèste*, reverses this order, and deduces the parallelogram of velocities from the parallelogram of forces. In his demonstration, however, he assumes that if two component forces, x and y, become successively dx, $2dx$, $3dx$, etc., and dy, $2dy$, $3dy$, etc., that their resultant z would become successively dz, $2dz$, $3dz$, etc., and the angle 0 between the directions of x and z would remain constant. But it seems to me that these results can only be considered to take place, on the hypothesis that force is proportional to velocity, and that they necessarily rest upon it. LaPlace does not admit this hypothesis until at a subsequent point of his investigation, and therefore his demonstration has that fallacy.

Lagrange says that Bernoulli attempted to establish the principle of the composition of forces on considerations independent of that of motion, and gave a complicated demonstration based on two "principles," but these *principles* also depend on that of *force proportional to velocity*, and it would seem that the parallelogram of forces involves essentially this principle, and cannot be freed from it.

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3. ON THE THERMO-DYNAMICS OF WATER-FALLS. By ALFRED M. MAYER, of South Bethlehem, Penn.

EVERY one standing before a cataract is impressed with the presence of power in the plunging water; and those who are accustomed to consider the evolution and transmutations of force naturally inquire into what phases of motion this falling mass is converted.

The cataract leaps the brow of the precipice and strikes the water below; vibrations are generated in the air, in the earth and water, and there arises a cloud of mist from the base of the falls. These are the immediately evident results of the falling water; but yet another effect we should naturally expect to find, that is, the heating of the water after its impact on the rocks and river beneath.

This effect has been suspected by all natural philosophers; but, as far as I know, no one attempted to detect and measure it until Prof. Joseph Henry made some thermometric observations at the Falls of Niagara in Sept., 1857. Prof. Henry gave a verbal account of his observations before the Baltimore meeting of the American Association for the Advancement of Science, in May, 1858; but unfortunately they were not presented for publication in the proceedings, and all that appears in the published account of that meeting is merely the following title: "Observations made at the Falls of Niagara, 1st September, 1857, by Prof. Joseph Henry." According to my recollection of the remarks of Prof. Henry, he did not detect any difference of temperature in the water at the top and bottom of the falls. This was probably owing to the want of delicacy in the thermometer, which read only to 1° Fahr., the fractions of degree being estimated by the eye aided by a lens.

I therefore, during a recent visit to Niagara and Trenton Falls, determined to repeat these observations with a delicate Centigrade thermometer, by Alvergniat of Paris, reading to 0°.02 Cent.

The first observations were made at Trenton Falls, July 4; the others at Niagara, July 7, 1869.

The water, at each place, was collected in a tin cylinder, attached to a strong cord, holding about a half-gallon and of sufficient depth to allow the thermometer to be entirely immersed; while the temperatures were read as soon as the mercurial column ceased to descend.

TRENTON FALLS, July 4, 1869.

Sky overcast. Drizzling. No perceptible wind. Temperature of air during observations 18°. 3, C.

The top-water was taken within ten feet of the leap of the falls; the bottom-water at about thirty feet from the bases of the two cataracts; and about five minutes elapsed between the last reading of the temperature of the bottom-water and the first reading of the top-water.

Sherman Falls (*Trenton*), *W. side.* *Height* 39 *feet.*

OBSERVATIONS.	TEMP. TOP-WATER.	TEMP. BOTTOM-WATER.
1	16°.6 C.	16°.7 C.
2	16°.6	16°.7
3	16°.6	16°.7

High Fall (*Trenton*) *upper fall W. side.* *Height* 45 *feet.*

OBSERVATIONS.	TEMP. TOP-WATER.	TEMP. BOTTOM-WATER.
1	16°.6 C.	16°.7 C.
2	16°.6	16°.7
3	16°.6	16°.7
4	16°.6	16°.7

At first sight these observations seem to have established an interesting physical fact in accordance with the thermo-dynamic theory; but the *same* degree of heating (0°.1 C) in each case, and the *amount* of the heating of the water does not agree with that which Joules' unit establishes; according to which the increase in temperature at the base of Sherman Fall should have been 0°.028 C, and at the High Fall 0°.032 C.

Niagara Falls, July 7, 1869.

W. side of Canada fall. Height 158 feet. Sky 0.7, cloudy; sun appearing at intervals. Wind S.; gentle breeze.

The top-water was here collected from an overhanging log, about sixty feet from the brow of the cataract and about thirty feet from the shore. The bottom-water was taken in first series of observations about two hundred feet from W. side of the base of fall, and in second series at about five hundred feet distant from base of cataract, to both of which points a strong current set in directly from the apex of "the horse-shoe," and the water when dipped was white with the air-bubbles it contained.

Niagara Falls. Observations at Top of Cataract.

OBSERVATIONS.	TEMP. TOP-WATER.	TIME OF OBSERVATION.
1	18°.85 C.	1.45 P.M.
2	18°.80	1.49
3	18°.80	1.52
4	18°.75	2.00
Mean Temp., . . .	18°.80	

Temperature of the air in shade with N. exposure, at top of the fall, during the observations, was 24°.00 C′.

Niagara Falls. First series. Bottom-water.

OBSERVATIONS.	TEMP. BOTTOM-WATER.	TIME OF OBSERVATION.
1	18°.6 C.	2.15 P.M.
2	18°.6	2.30
Mean Temp., . . .	18°.6.	

Niagara Falls. Second series. Bottom-water.

OBSERVATIONS.	TEMP. BOTTOM-WATER.	TIME OF OBSERVATION.
1	18°.55 C.	2.40 P.M.
2	18°.60	2.43
3	18°.55	2.50
Mean Temp., . .	18°.566 C.	

Mean Temp. of first and second series, 18°.583.

Mean Temperature of air at bottom of cataract, from five observations, was 22°.16 C.

The above observations show that the water after having reached the point at the base of the cataract where it was collected was *cooled* 0°.217 C, instead of being *heated* 0°.113 C, as should have taken place had all of the falling force of the water been converted into heat.

Thus at Trenton Falls we obtain a + and at Niagara a — departure from the deductions of a well established theory. In order to appreciate these apparently anomalous results we should consider the physical conditions of the water during and after the fall.

As the water approaches the brow of the precipice, and just after it makes the leap, it has different velocities at various points of section at right angles to its surface, the velocity of its particles decreasing with the depth from the surface owing to the friction of the lower strata on the river-bed. This difference of velocity first tends to break up the sheet and then the resistance of the air (which increases with the square of the velocity of the falling particles) further disintegrates the liquid; and when the sheet is thin, and the fall high, it will be completely "*atomized*," as we see in the Falls of the Staubach and of Yosemite. As the fall strikes the river below it forces under its surface a large quantity of air, and thus during and after its fall the water is under conditions most favorable for its evaporation.

When the surrounding atmosphere has a temperature above that of the top-water it will give up part of its heat when it is forced under the surface of the river below, and if the sheet be unbroken (as was nearly the case at Trenton Falls) this heating cause will be added to the heating effect of the impact. While if the sheet is disintegrated during a high fall (as at Niagara) the cooling by evaporation may equal and even surpass the heating produced by these two causes. It therefore follows that with the same temperature of top-water different temperatures will be obtained at the foot of the same fall, according to the various hygrometric and barometric conditions of the atmosphere.

Now, if we suppose that the water falls in an unbroken sheet of considerable thickness, that no vibrations of air, water and earth are produced, and that no heat is given by the atmosphere or abstracted by evaporation, we will have the total falling force converted into heat, and that easily detected with a thermometer as delicate as that used in these observations. The heating effect would be in proportion to the height of the cataract or, what is the same, as the square of the velocity of impact; a fall of seven hundred and seventy-two feet being requisite (according to the experimental determinations of Joule) to heat the water 1° Fahr., which converted into centigrade equivalent gives $772 \times \frac{9}{5} = 1390$ feet of fall for an elevation of 1°, Centigrade.

Thus we see why it was that at Trenton we obtained a heating effect of 0°.1 C., while theory gives 0°.032 C. (for the mean of the two falls), while at Niagara we obtained a *cooling* effect of 0°.217 C, instead of 0°.113 C. of heating; showing that the water was really *cooled by evaporation* $0^{\circ}.217 + 0^{\circ}.113 = 0^{\circ}.33$ C., without considering the abstraction, by the same cause, of the heat imparted to the water by the air, which must have been considerable as its temperature exceeded that of the top-water by 5°.2 C.

We infer from our observations that one cannot derive from thermometric observations on water-falls any data of value to the thermo-dynamic theory; but we would suggest that observations be made when the temperatures of the air and of the top-water are alike, while at the same time the air is saturated with moisture; under these conditions the heating of the water due to its impact will be the least hidden by the heating or cooling effect of contiguous air, or by the cooling produced by evaporation. Observations should also be made under very different thermometric, hygrometric and barometric conditions of the atmosphere, which would give approximations to the measure of their several effects.

We have no doubt that the results which will be obtained under circumstances when these extraneous disturbing causes are at a minimum, will give a residual heating effect due to the impact of the falling water, and its determination under these conditions is worthy of the attention of any one who has the advantage of proximity to the falls and the leisure and patience to make the observations.

4. PHYSICAL THEORY OF THE PRINCIPLE OF THE LEVER. By W. A. NORTON, of New Haven, Conn.

IF it be true that two forces acting upon a lever will hold each other in equilibrio if their intensities be inversely proportional to their lever arms, it is plain that this principle must be a consequence of the law or laws, of the lateral transmission of force from molecule to molecule of the lever, and therefore of one or more fundamental principles of molecular action consequent upon the disturbance of the natural equilibrium of the molecules. I propose to show that it may in fact be deduced from two admitted principles of molecular action. These are:

(1) If two integrant molecules of a solid body, which lie within the range of reciprocal action, be forcibly separated from each other a minute distance, a mutual attraction or repulsion will be brought into operation, and if they be urged

nearer to each other by an equal minute distance an equal opposite force of repulsion or attraction will come into play.

(2) The intensities of the forces thus originating are proportional to the amount of the relative displacement of the two molecules, on the line connecting them.

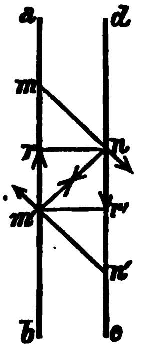
To these fundamental principles are to be added that of the parallelogram of forces, as applicable to the case of two forces acting *directly* upon the same point.

The principle of the lever presents three distinct cases, which require separate consideration.

1. *The Straight Lever, with perpendicular forces.*
2. *The Straight Lever, with oblique forces.*
3. *The Bent Lever.*

Case i. *The Straight Lever, with perpendicular forces.* We will first take the lever of the first order, and consider the precise process of transmission of either of the extraneous forces acting upon it from the point of application to the fulcrum. Let *ab*, Fig. 1, represent a vertical line of particles of one cross section, or lamina, and *cd* the contiguous vertical line of particles of the next section; and let us conceive that all the similarly situated pairs of lines of the two cross sections or laminæ, are concentrated upon *ab* and *cd*, so that these lines may represent the entire cross sections.

Fig. 1.

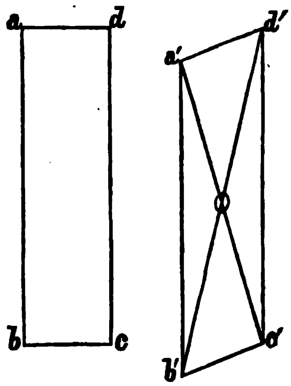


Suppose that the extraneous force is directly applied to the first line, depressing it by a small amount. If we take one particle m' of the first line and consider the actions upon it of two particles n, n', of the second line at equal distances above and below it, it will be seen that m' will recede from n a minute distance, and approach n' by sensibly the same distance, and that the molecular forces brought into operation by these relative displacements will be opposite in their character, and equal in intensity. Thus, if the recess of m' from n develops a mutual attraction, the approach of m' to n' will develop an equal repulsion. The resultant of these two forces acting on m' will be directed upward, or from m' toward a. A similar result will be obtained for each pair of particles, *n* and *n'*, that exercise a sensible action on *m'*; except that for those situated beyond a certain distance the forces developed, and consequently their resultants, will be reversed, or *m'* will be urged downward by the actions of such particles. Since *m'* is held in equilibrium in opposition to the extraneous force urging the section *ab* downward, the entire resultant of all the actions of the pairs of particles *n*, *n'*, of the section *cd*, on *m'* will be directed upward. The section *ab* slips upon *cd*, under the action of the extraneous force until this resultant is equal to the extraneous force. By our second fundamental principle the amount of this slipping will be proportional to this force; since the actions of each pair of particles, *n*, *n'*, will be proportional to this displacement.

Now if we take any particle *n* of the section *cd*, and consider the actions on it of two particles *m*, *m'*, at equal distances above and below *n*, and at the same distances that *n* and *n'* are above and below *m'*; then, if the actions of *n* and *n'* on *m'* are such as to give a resultant directed upward, the actions of *m* and *m'* on *n*, will give a resultant directed downward, as shown by the arrows in the figure. These two resultants will be equal to each other. It follows, therefore, that the entire action of *ab* on *n* will be represented by a force acting downward equal to that by which *m'* is drawn upward by the action of *cd* upon it. This force will then be equal in intensity to the extraneous force. Accordingly the extraneous force will be transmitted from *ab* to *cd*; and in the same manner from this section to the next, and so on to the point of support. The transmission is effected by the slipping of each vertical section, or lamina, by the same amount upon the next, and so developing reciprocal vertical actions equal to the extraneous force.

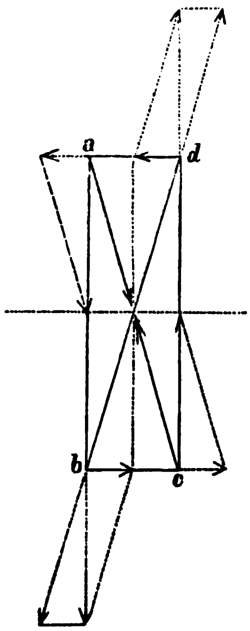
Let us next seek to determine the longitudinal strains on the fibres, developed by the extraneous force in the process of lateral transmission just considered. Let *ab* and *cd*, Fig. 2, represent two vertical cross sections of the lever indefinitely near to each other, of which *ab* directly receives the force applied to one end of the lever. The relative slipping of contiguous laminæ causes the rectangle *abcd* to take the figure of

Fig. 2.



an oblique parallelogram, $a'b'c'd'$; the diagonal ac being shortened, and the diagonal bd being lengthened. It therefore developes forces of compression taking effect from a' and c' toward the centre o of the parallelogram, and forces of extension taking effect from o toward b' and d'. The reactions to these forces take effect from o toward a' and c', and from b' and d' toward o. These reactions will urge the points a' and d' toward the left, and the points b' and c', toward the right; and the longitudinal strains on the fibres $a'd'$ and $b'c'$, thus originating at the angular points of the parallelogram, will be equal. For, supposing that there are only these extreme fibres, and that the diagonals $a'c'$ and $b'd'$ are material lines, the figure $a'b'c'd'$ is to be regarded as a system in equilibrium under the action of two equal forces along its vertical sides; that along $a'b'$ being the active force and directed downward, and that along $c'd'$ being the equal reaction of the fixed support transmitted to $c'd'$, and directed upward. One-half of each of these vertical forces will act at the upper and lower corners of the parallelogram. The reactions along the diagonals, above alluded to, will at these points sustain the equal vertical forces acting on them, and at the same time develope equal longitudinal strains on the fibres $a'd'$ and $b'c'$. Or, more directly we may regard the equal vertical forces, at the four angular points, as taking effect at the same time along the diagonals and along the fibres. This is illustrated in Fig. 3, in which the vertical forces soliciting the angular points of the parallelogram are represented by the halves of its vertical sides, or by equal lines. It will be seen that the longitudinal strains developed at these points will be represented by the halves of the horizontal sides; and therefore that the entire strains on the extreme fibres, due to the parallelogram considered, will be represented by these sides, ad and bc. If now we take the case as it actually is, and regard the entire area, *abcd*, as made up of fibres, the only result will be that the longitudinal strains which, upon the previous supposition, would be developed along *ad* and *bc*, will be distributed over all the fibres lying between these extreme fibres and the middle one. What the law of the distribution may be it does not concern us now to inquire. It is plain that the individual strains will decrease from the outer fibres toward the middle one, where there will be no strain.

Fig. 3.



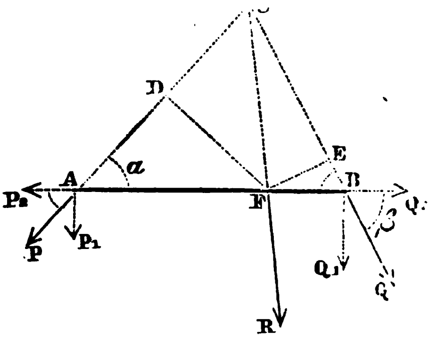
If now we take another vertical section indefinitely near to *cd*, it will form with *cd* another parallelogram, the vertical sides of which will be solicited, in opposite directions, by the same forces as those of the parallelogram just considered. The same strains as before will therefore be developed along the upper and lower fibres by these forces. The same will be true of each successive parallelogram into which the arm of the lever may be divided. The actual strain along any one continuous fibre, at the fulcrum, will therefore be equal to the strain on this fibre developed by any one of the parallelograms, multiplied by the number of parallelograms in the extent of the arm of the lever. Now if we suppose the two lever arms to be of unequal length, whatever may be the comparative intensities of the two forces that balance each other, each will give rise to a slipping of contiguous vertical sections, or laminæ, of its lever arm, proportional to those intensities, and so develop longitudinal strains on any fibre, in the extent of any single parallelogram considered, proportional to the same. Let p and q represent these proportional strains on a single fibre, and P and Q the forces applied to the lever, then $p:q::P:Q$. Let m represent the arm of lever of P, and n that of Q. The number of equal parallelograms contained in these lever arms will be proportional to their lengths, m and n. The strain on the fibre considered, at the fulcrum, resulting from the action of P, will then be denoted by pm, and that resulting from the action of Q by qn. But the equilibrium requires that these directly opposite strains should be equal; and therefore $pm = qn$. Hence $p : q :: n : m$; and therefore $P : Q :: n : m$.

Since each of the forces P, Q, is transmitted to the fulcrum, by the slipping of each vertical section of the lever on the next, without change of intensity, the pressure there will be equal to the sum of P and Q.

The theory of the lever of the second order, as well as of the third, is essentially included in that of the lever of the first order; since the reaction of the fulcrum of the latter may be replaced by an active force, and either of the forces P, Q, by the reaction of a fulcrum.

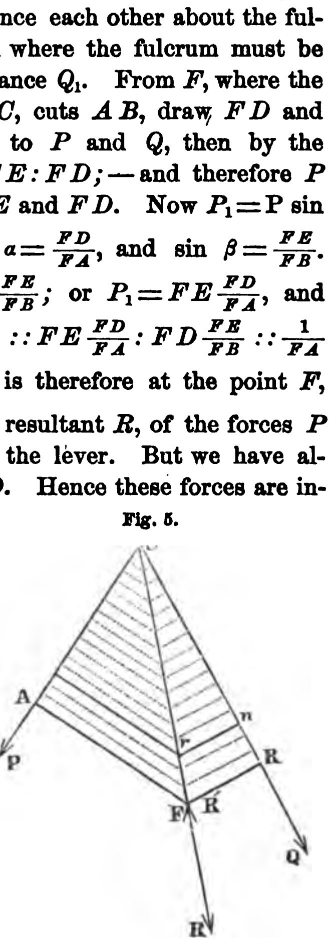
CASE II. *Straight Lever with oblique forces.* Let $A B$, Fig 4, represent the lever, and P, Q, forces obliquely inclined to it,—the system being in equilibrium about some fixed point intermediate between A and B. Produce P and Q to their point of intersection C, and let $C F$ be the direction of their resultant R, supposing them, for the moment, to act at C. Wherever the fulcrum may have to be in order that P may balance Q, P and Q will be transmitted to it, by the process of molecular lateral transmission that has been explained, without change of direction or intensity, and therefore give a resultant pressure, R', on it, having the same intensity and direction as R acting at C. Decompose P and Q as shown by the arrows, and suppose R' to be similarly decomposed into the components R_1 perpendicular to the lever, and R_2 lying in it. Then, since R' is the resultant of P and Q transmitted to the fulcrum, we have $Q_2 - P_2 = R_2$, and $P_1 + Q_1 = R_1$. Thus P_2 and

Fig. 4.



Q_2 are neutralized by the component of the reaction of the fulcrum (which is equal and opposite to R') in the direction of the lever; since this component is equal and opposite to R_2. It follows, therefore, that the two components, P_1 and Q_1, perpendicular to the lever, will balance each other about the fulcrum. It now remains to be seen where the fulcrum must be situated, in order that P_1 may balance Q_1. From F, where the line of direction of R, through C, cuts AB, draw FD and FE, perpendicular, respectively, to P and Q, then by the parallelogram of forces, $P : Q :: FE : FD$; — and therefore P and Q may be represented by FE and FD. Now $P_1 = P \sin \alpha$, and $Q_1 = Q \sin \beta$; and $\sin \alpha = \frac{FD}{FA}$, and $\sin \beta = \frac{FE}{FB}$. Hence $P_1 = P \frac{FD}{FA}$, and $Q_1 = Q \frac{FE}{FB}$; or $P_1 = FE \frac{FD}{FA}$, and $Q_1 = FD \frac{FE}{FB}$. Therefore $P_1 : Q_1 :: FE \frac{FD}{FA} : FD \frac{FE}{FB} :: \frac{1}{FA} : \frac{1}{FB} :: FB : FA$. The fulcrum is therefore at the point F, where the line of direction of the resultant R, of the forces P and Q supposed to act at C, cuts the lever. But we have already seen that $P : Q :: FE : FD$. Hence these forces are inversely proportional to their technical lever arms, FE and FD. As P and Q are transmitted to the fulcrum without change of direction or intensity, the pressure on the fulcrum will be equal to R.

Fig. 5.



CASE III. *The Bent Lever.* Let P and Q, Fig. 5, be two forces acting on two points A and B of a body of indefinite extent, capable of turning about a fixed point F, situated in the plane of the lines of direction of P and Q. Produce these lines of direction to their point of intersection C; and from F draw the perpendiculars FA and FB. Divide FC into an indefinitely great number of equal parts, and from the points of division draw parallels to FA and FB. Let us first suppose that the point *C* falls within the body, and that this is of uniform thickness in a direction perpendicular to *A C B F*, and has the form *A C B F*. The perpendiculars to *P* and *Q*, from the points of division of *F C*, will divide the body, conceived to be represented by the area *A C B F*, into an indefinite number of similar portions of the bent lever form, with the points of intersection of the two arms on the line *C F*. Now let *a* represent the cross section of any one of these, on the line of *P*, and *b* the cross section of any one on the line of *Q*. *P* will be equally distributed over the entire cross section *A C*, and *Q* in the same manner over *B C*. Let *p* and *q* denote the fractional portions of *P* and *Q* that take effect at the ends of any one of the bent lever portions of *A C B F*. If we consider any one of these portions by itself, it will be solicited by the forces *p* and *q*, and be in equilibrium under the operation of these forces and some portion of the reaction *R'*, to the pressure *R*, on the fulcrum, produced by *P* and *Q*. They will be transmitted inward by the slipping of contiguous sections, and neutralized by a certain portion of *R'* transmitted along its line of direction; and the point in which this line intersects the bent lever portion under consideration must be its virtual fulcrum. Now if we consider the bent portion next to *C*, its fulcrum must be indefinitely near to *C;* while that of the first elementary bent lever, *A F B*, lies at *F*. But all the fulcra of the elementary levers must lie on the line of direction of *R'*, which passes through *F*. Hence, as *C* is the fulcrum of one of these levers, this line of direction must also pass through *C*. Now the direction of *R'* is opposite to that of the resultant *R*, of *P* and *Q* supposed to act at *C;* since *R'* neutralizes *P* and *Q* transmitted, without change of direction or intensity, to *F*. Therefore, as its line of direction passes through *C*, it must coincide with the line of direction of the resultant *R*, of *P* and *Q* supposed to take effect at *C*. It follows, then, that the fulcrum, *F*, lies on this resultant. But, by the principle of parallelogram of forces, we have, for any point, *F* on the resultant, the proportion $P : Q :: FB : FA$.

Now suppose a portion, *C m r n*, of the body *A C B F*, to be removed; the equilibrium will not be disturbed, since the only effect will be to augment the intensities of the fractional parts of P and Q that act on the elementary bent levers of the remaining portion, $m\,r\,n\ B\,F\,A$, without altering their ratio. Hence the forces, P, Q, which act on a bent lever and hold each other in equilibrio, are inversely proportional to their lever arms.

It will be seen from what has been stated, *in what manner the forces P and Q become neutralized by the action of R', or the reaction of the fulcrum.* Even when their point of intersection, C, falls within the body, they cannot be regarded as actually transmitted to C, and taking effect wholly there in opposition to R' transmitted and taking effect wholly at the same point. As a matter of fact it is only an infinitesimal portion of each force that operates at C. An equal indefinitely small portion, p, q, or r, acts upon each elementary lever; and each triplet of forces taking effect on each elementary lever, counteract each other. In other words, the forces P and Q, instead of taking effect by direct transmission, wholly either at C or F, are actually distributed along the whole length of the portion of the line $F\,C$ that falls within the lever, and are there neutralized in equal elementary portions, by the corresponding elementary portions of R', transmitted to the same points.

If we suppose the body on which P and Q act, to have an indefinite extent, the only portion whose molecular forces will be called into play, in the transmission and counteraction of the forces, will be that comprehended within the lines of direction of P and Q. This will comprise the part $A\,C\,B\,F$ already considered, and another part lying on the other side of $A\,F\,B$, that is on the side toward which P and Q solicit the points A and B. This part may be subdivided into elementary bent levers like the other, and its existence will have no other effect than to diminish the absolute values of p, q, and r, the triplet of forces answering to any one of the whole number of elementary levers, into which the entire portion of the body that lies within the lines of direction of P and Q is divided. It will be observed that for each elementary lever of this part, the resultant of the forces p and q will take effect upon the fixed point F, as a force of traction, instead of as a force of pressure, as in the case represented in Fig. 5.

We thus arrive at the general principle, that if two forces, whose lines of direction when produced intersect each other, are applied to a body capable of turning about a fixed point in the plane of these lines, these forces will be in equilibrio, provided *the statical moment of the one force is equal to that of the other.*

III. ASTRONOMY.

1. SPECTRUM OBSERVATIONS AT BURLINGTON, IOWA, DURING THE ECLIPSE of AUGUST 7, 1869. By C. A. YOUNG, of Hanover, N. H.

THE instrument employed was the same referred to in my next paper "on the use of the spectroscope in observing contacts at a solar Eclipse." A comet seeker of four inches aperture and thirty focal length, throws, by the help of an eyepiece, an image of the sun, about two inches diameter, upon the slit of the spectroscope. The collimator and observing telescope of the spectroscope, made by Clark, have each an aperture of two and a quarter inches and a focal length of about seventeen inches. The dispersion is produced by a train of five heavy flint glass prisms with angles of 45°, each, and faces two and a quarter by three inches. They give a refraction of 165° (for the D line) and a dispersion of about 18° from A to H. The eye telescope is carried over the spectrum by a tangent screw, but all determinations of the positions of lines have to be made by a micrometer in the eye-piece. The instrument is provided with an arrangement for throwing an air spectrum formed between platinum wires by the spark from an induction coil, into the field of view along side of the spectrum under observation.

While the eclipse was coming on, special attention was directed to the moon's limb, in order to detect if possible indications of an atmosphere. The results were solely and remarkably negative. The dark lines of the solar spectrum came up squarely and exactly to the moon's limb without the slightest curvature or distortion, whether the slit was tangent or perpendicular to it. The contrast in appearance between the limb of the sun and that of the moon was very striking. When the image of the sun's limb was brought to the middle of the slit the line of demarkation between the bright and dark portions of the spectrum was always more or less hazy, however carefully the instrument might be put in focus; different portions of the limb also differed very much from each other in this respect, some being far less sharp than others; but when the moon's limb was similarly placed it was as sharp as could have been drawn with a pen. Of course the cloud-like nature of the solar photosphere accounts for its comparatively indefinite outline.* Secchi's *continuous* spectrum at the edge of the sun I have never seen; the stratum which produces it (if there is such a stratum) must have a thickness little if at all exceeding 1″. During the totality there was in the field of the spectroscope a faint continuous spectrum, undoubtedly from the corona, without any visible traces of *dark* lines; a fact rather surprising, considering the polarization of this light, which was so complete that when the axis of a tourmaline, held in the hand over the eye-piece, was placed parallel to the limb of the sun the faint spectrum nearly vanished.

Upon this spectrum were superposed a number of bright lines when the image of a prominence was thrown upon the slit. Nine of them were seen by me, viz.: *C*, *K*, 1017.5 (near *D*) and which for convenience I will refer to as the D_3 line; a faint line near 1250 *K* (by estimation), another faint line about *K* 1350 (also by estimation), a conspicuous line *K* 1474 (3503 of my scale) just below *E*, *F;* a pretty conspicuous line at *K* 2605 ± 2 (by measures), *K* 2796, just below *G*, and *h*. I did not see any line at *b*, but presume it was passed over without proper examination in the manner I will presently explain. There can be no doubt I think, that it was conspicuous enough in the great prominence on the *W* edge of the sun, as seen by others. But in sweeping along the spectrum with my tangent screw beginning at *C*, I noticed on coming to the 1474 line that it extended *clear across the spectrum* which was not the case with the *C* and *D* lines, since the protuberance on the *SE* limb then on the slit only had a height of about 1½′. (The slit is 2′ 54″ in length.) This fact at once arrested attention and led to the suspicion that this line, *K*, 1474 (which I first noticed in July, and described in the last number of the Journal of the "Franklin Institute," published a few days before the eclipse) was not a protuberance line at all, but *due to the corona;* and on moving the slit of the instrument entirely off from the protuberance this line remained, while the golden D_3 line disappeared.

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* This polarization may have been produced, as suggested by Prof. Pickering, by the successive refractions at the faces of the prisms.

It now became necessary, on account of the moon's advance, to bring the other side of the sun's image to the slit by the right-ascension screw; and I imagine that while the assistant was doing this I continued to carry along the spectroscope-telescope by its tangent screw, thus passing over the region of *b*, while the telescope was pointed nowhere in particular. But I am ashamed to say that I have no recollection at all about it, nor can I recall distinctly the behavior of the two faint lines between *D* and *E*, though my strong impression, as recorded immediately after the eclipse, was that they also were, like 1474, *corona* lines. The line *K*, 2602, had its position determined by micrometrical reference to *K*, 2796, and just as that measurement was completed the sun came out, and all the new lines, not previously observed in full sunlight, instantly disappeared. The feeling of chagrin and surprise at thus being cut short was almost overpowering — the sense of wasted opportunity and personal imbecility. No line was seen at *K*, 660, below *C*, where I have twice before seen and measured one. I saw nothing of the difference between the spectra of the different prominences reported by some of the observers, but as I observed one part of the spectrum with one prominence in the slit, and the rest with another, it need not be wondered at. While the great dispersive power of my instrument gave great advantage for the observation of faint lines, and the accurate determination of position; it had also great disadvantages in the smallness of the field, and the time required for an exploration of the whole spectrum.

But I wish to call the special attention of the section to another point in this connection. The line *K*, 1474, in the *corona spectrum* coincides with a line in the spectrum of the

Aurora Borealis reported, by Prof. Winlock, in the last number of "Silliman's Journal," at 1550 of Huggins' scale, as nearly as I can determine by the comparisons of the two scales given in Prof. Gibbs' recent paper on wave lengths by the method of comparison. If the lines do not absolutely coincide, the distance between them can hardly equal one division of either scale. The first Aurora Borealis will enable any one, with a spectroscope, to settle the matter accurately by measuring the distance from *b* (produced by burning a bit of magnesium before the slit) to this line. I have been very much disappointed at not having had an opportunity to do this before reading this paper. Furthermore, two other of the five Aurora lines reported by Prof. Winlock, viz.: 1280 and 1400 of Huggins' scale agree, fully within the limits of error, with the two faint lines between *D* and *E*, which I suppose are also corona lines. Taking these facts in connection with the peculiar radiating structure of the corona and some of the prominences, and their rapid changes of form and brilliancy, does it not become very probable that our own Aurora Borealis, and these wonderful emanations from the sun are kindred, if not identical pheonomena?

Possibly, hereafter, spectroscopic observation of the prominences, and of the intensity of this corona line, which though rather difficult in my instrument could be easily observed with one of higher dispersive power, may lead to farther light when combined with magnetic observations.

This line is given by both Kirchoff and Angstrom as an iron line, though faint and very close to two other much more conspicuous lines produced by the same substance; the same is also probably true in respect to the two other lines of the corona, which appear to coincide with lines given as iron on the charts. It is certainly worth inquiry if there is not some misconception in this, and whether, since *iron* can scarcely be conceived to exist in a gaseous state in those terrestrial regions where the Aurora Borealis resides, it may not always have associated with it some other substance, which also can exist separately as a gas of inconceivable tenuity. But this belongs to the chemists.

I ought to add here, that since the preparation of this paper

Prof. Winlock has informed me that he has thought of, and published, the same idea as to the probable identity of our Aurora and the Corona, though not based on any comparison of spectra.

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2. ON A NEW METHOD OF OBSERVING THE FIRST CONTACT OF THE MOON WITH THE SUN'S LIMB AT A SOLAR ECLIPSE BY MEANS OF THE SPECTROSCOPE. By C. A. YOUNG, of Hanover, N. H.

AT the recent solar eclipse, observed by the writer at Burlington, Iowa, as a member of the party, under the direction of Prof. Coffin, Superintendent of the American Nautical Almanac, the instant of the first contact was determined by means of the spectroscope, in a manner which is believed to be entirely novel and to admit of much greater accuracy than has ever been attainable heretofore in this kind of observation.

In the instrument employed, a telescope of four inches aperture and about thirty inches focal length (a so-called comet-seeker) was arranged to throw an image of the sun about two inches in diameter upon the slit of the spectroscope. The slit is one-eighth of an inch long; its width adjustable. A circular plate of brass about two and a half inches in diameter, with a hole also one-eighth of an inch in diameter at its centre, was attached by a hinge in such a manner that it could be turned down over the slit; it was covered with paper and graduated by radiating lines into angles of 10°, and furnished the means of bringing on the slit the portion of the sun's limb which was indicated by calculation as the point of contact.

A train of five flint glass prisms, with refracting angles of 45° formed the spectrum which was viewed by a telescope of two and a quarter inches aperture (the same as the collimator) and about seventeen focal length, with a magnifying power of eighteen. The spectrum, referred to the limit of distinct vision, was about one and three-fourth inches wide by four feet long. The whole arrangement was mounted equatorially, with slow motion screws, etc. I have been somewhat particular in describing the instrument as it is likely the method about to be presented for your consideration might prove impracticable with a single prism instrument. High dispersive power is neccessary. The equatorial mounting is also important.

When now the image of the sun's limb is made to bisect the slit at right angles or nearly so, the spectrum will present something the appearance indicated in the diagram. One-half (formed by the sun) will be brilliant, the other will be comparatively dark, being formed mostly by the light reflected from the air in the sun's immediate neighborhood. The spectrum of the sun's chromosphere, however, is superposed upon the air spectrum and becomes visible in certain bright lines, especially the *C* line, which is by far the most easily observable; and the effect is this: most of the dark lines extend clear across both portions of the spectrum, the dusky as well as the brilliant; not so with the *C* line. This is intensely black on the brilliant portion of the spectrum, but is continued in the dusky portion by a little needle of brilliant red light, of a length ranging in my instrument from an eighth of an inch upwards. When a protuberance is in the slit it often reaches clear across, but generally is not more than a quarter of an inch long. In other words, the *C* line instead of simply extending across the whole spectrum like the other lines, has a portion of its length, beginning at the boundary between the bright and dusky portions and extending into the dusky portions, replaced by a *bright* line. This bright line is usually somewhat *pointed* at the outer end.

Now suppose that the portion of the limb on the slit is that where the moon is to strike. As the depth of the chromosphere is seldom less than ten to fifteen seconds of arc, the moon will reach *its* outer edge some twenty or thirty seconds before the time of true contact with the sun's limb, and the observer will see the little *red needle* which I have described; first squarely truncated,—its point cut off—and then gradually and steadily shortened until at the instant of actual contact it disappears, and the *C* line becomes exactly like its neighbors. The observation in this way is as easy and certain as that of the transit of a moderately slow star. I do not think an error of more than half a second possible with reasonable care, and it ought to be less.

At the eclipse of August 7, I saw in the manner I have described, the moon's approach to the sun's limb, and noted its contact about five seconds earlier than any of those who were observing by the ordinary methods, and differed among themselves some ten seconds. I have been much gratified also to learn from Prof. Mayer, who had charge of the photographic operations of our party, that the time of first contact, deduced by measurement and computation from a photograph taken as soon as possible after the contact had been signalled to him from the other observers, agrees with my own observation within three-tenths of a second.

The same method would of course apply with slight modifications, to the observation of the other contacts, but I am not aware that it presents any advantage over the older methods.

I desire to call special attention to the applicability of this method in the approaching Transits of Venus. Undoubtedly the atmosphere of the planet, and irradiation will interfere with its accuracy to some extent, but I think no more than with other methods, and it must certainly be much to the observer's advantage to be able thus to *perceive*, if he cannot be properly said to *see*, the planet before she strikes the sun, and watch her approach.

At the internal contact also, I think the sudden formation of a long horizontal line of light extending the whole length of the spectrum would be a much better phenomenon to observe accurately than the rupture of the black ligament, about which so much has been said in this connection.

I cannot help feeling that this method of observation ought to be provided for in any expeditions that may be sent out to observe the Transits.*

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* Having lately received the volume of the *Comptes Rendus* of the French Academy of Sciences for the first half of the current year, I find that I have been anticipated by M. Faye in respect to this method of observing the contact of an opaque body with the disc of the sun. At the session of Monday, January 11th, 1869, in a discussion upon the observation of the coming transit of Venus, he proposed essentially the same use of the spectroscope which I have described in the foregoing article.

3. OBSERVATIONS ON THE ECLIPSE, WITH AN ARAGO'S POLARISCOPE AT MT. PLEASANT, IOWA. By EDWARD C. PICKERING, of Boston, Mass.

OBSERVATIONS of previous eclipses have led to the belief that the light of the corona is polarized in planes passing through the centre of the sun, and therefore that it shone by reflected light. It was with the expectation of verifying these views that I prepared an Arago's polariscope to observe the recent eclipse. This instrument consists of a tube closed at one end by a double image prism of Iceland spar, and at the other by a plate of quartz. Looking through the spar we see two images of the quartz of complementary colors (in this case blue and orange) when the light is polarized. Although this polariscope is somewhat less delicate than that of Savart, yet it enables us to determine the condition of the light emanating from every part of an object, by noting the color of its image. If, now, the corona was polarized as above described, in one image the upper and lower parts would be blue, those on the right and left yellow; while in the other image these colors would be reversed, the yellow above and below, and the blue on the sides. In reality the two images were precisely alike, and *colorless*. But one was on a *blue*, the other on a *yellow* background. Consequently the corona was not polarized. This does not prove that the corona is self-luminous, as the light reflected by the clouds is unpolarized, and in general polarization is produced by specular, and not by diffuse reflection. The colored background proves that the sky close to the corona was strongly polarized in a plane which was independent of the position of the sun, since it was the same on all sides of it.

The following explanation of this curious effect is suggested. The earth beyond the limits of the shadow is strongly illuminated and acts as an independent source of light. The reflection of its light by the sky, would produce the effect just described.

The corona was also examined by a double image prism of spar, and by this, also, was seen to be unpolarized.

IV. ELECTRICITY.

1. Causes of the Failure of Lightning Rods. By James Bushee, of Worcester, Mass.

Perhaps few subjects can be deemed of greater practical interest to the public than that of protecting life and property from the effects of atmospheric electricity.

Since the time of Franklin, the well known metallic rods have been used in this and other countries, as a means of security, and scientific men have very generally, if not universally, acknowledged their utility, when the laws of electricity are properly regarded.

In this section of New England,* thunder storms are common during the summer, and sometimes very violent, while certain localities seem to be more especially exposed to frequent and powerful electric discharges.

In some casual observations of the effects of lightning, my attention was called to the significant fact that a large majority of the buildings injured by lightning had rods attached to them for the purpose of protection.

Instances were not unfrequent where dwelling houses, with rods, were "*struck*" and damaged, while those in the immediate vicinity, without rods, escaped unharmed; sometimes houses with no rods have stood many years uninjured, but soon after the application of rods they have been struck by lightning.

Such facts have led some candid and intelligent persons to doubt the efficiency of lightning conductors, while others have been induced to reject them altogether as wrong in principle and dangerous in practice. But error in the interpretation of phenomana, or in the application of a scientific truth, does not invalidate the integrity of the principle itself. The fundamental idea of Franklin is doubtless correct, and the unfavorable results so often witnessed are but the legitimate fruits of wrong application. If so it is evident the cause of failure lies in defects which have a potential remedy, and that too in the truthfulness of the very law which is often unjustly made responsible for consequences—for the evils invariably disappear just in proportion as we are enabled to fulfil the highest conditions of that law.

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*Worcester, Mass.

What then is the cause of the many casualties from lightning where rods are used?

With the view of meeting this enquiry I have made it a special point for several years past to examine, as carefully as I could, the principal accidents which have come to my knowledge in Worcester and vicinity; also various cases of interest in other localities.

From obvious results of observation it appears:—1. That buildings have been struck in numerous instances, and more or less damaged, with all the different kinds of rods commonly used in New England, irrespective of form, style or material—whether of iron or copper—not, however, that all are equally defective, or that all are constructed with equal fidelity and scientific skill, but none have completely fulfilled the object intended. 2. That the leading defects of rods in general, and the cause of failure to protect buildings, are due, in part, to their construction and arrangement, but *principally to their imperfect connection with the ground, and the inadequate conducting power of the materials with which the rod comes in contact.*

As regards the construction and application of the rod the directions usually given by good writers on the subject are all, perhaps, that could be desired, if they were properly observed by constructors; but first principles are too often sadly overlooked in the outset—besides the rod is liable to become defective by long neglect. The joints should be kept in perfect contact to preserve the entire continuity of the conductor. If the rod is badly rusted, especially the part connected with the ground, its capacity for conveying a heavy charge is materially impaired. When the tip of the rod becomes oxidated and blunt the charge is liable to become more sudden and disruptive, whereas a sharp and perfect point receives the electricity *gradually* and begins to effect a discharge at a greater distance, giving time for the whole charge to be harmlessly conveyed to the earth.

Short crooks towards the building, and abrupt changes in the size or conductivity of the rod, tend to induce lateral discharges. The rod should not diminish in size or capacity from the top downwards, but rather increase in conducting power as the charge descends.

An objectionable feature in the application of the rod appears where two or more *receiving* points are erected upon the roof, and terminated in a single rod extending to the ground, or where the rod is turned upward from the point, over some higher parts of the roof, even higher than the point itself.

In such cases it is found that the lateral discharge usually takes place at the lowest point of the bend, or at the point of junction where two or more rods terminate in one.

Independent of any hypothesis, as to the nature of electricity or its mode of action; whether any distinct fluid ever passes up or down the rod in case of a thunder storm; or whether all the effects witnessed are due simply to induction and polarization, there is no less actuality and power in its operation. The agency with which we have to deal is no less real or tangible in its effects. We may therefore regard electrical phenomena as the result of a dynamic force which bears a striking analogy, in some respects, to other forces that are governed by well known dynamic laws. So far then, as this analogy holds, it may lend some aid in forming correct conclusions.

Suppose for example a rod has two arms, or branches, erected perhaps upon the chimneys of a house, and forming a connection with the main rod somewhere on the roof; and suppose, also, that the electric force is conceived to act from the top downwards, requiring time for its transmission through the rod. Now should a heavy charge be received at the same time upon both arms of the rod, the two electric forces pursuing the irrespective channels of conduction, rush together at the point of junction, where, for an instant, the intensity is greatly increased, while the single rod below this point being no larger than either branch, and having but half the conducting power of both, is unable to carry the double charge so suddenly imposed upon it, and hence a portion of the burden is forced to seek an unnatural channel of escape through the building.

A moderate charge even, which the capacity of the rod might easily convey, under favorable circumstances, may became so intensified at certain points, by a sudden augmentation of electricity — as by the meeting of opposite currents, or an abrupt reduction of conductivity — that a lateral discharge would ensue before requisite time could elapse for the electric force to adjust itself to the new condition of things. This arrangement appears to be equivalent to reducing at once the conducting power of the rod to half its former dimensions.*

The second and principal cause of failure is due to the defective mode of connecting the rod with the ground; the inadequate means provided for the escape of the charge from the conductor into the earth.

It is a common practice to run the rod into the ground from four to six feet, or until it is supposed to reach the moist earth, and this is generally considered quite sufficient for all practical purposes, and the numerous agents employed by different manufacturing companies to supply rods throughout the country, seem to believe that when thus much is done their duty is fully accomplished, and that the rod can then be left, in good faith, as a safe and reliable protection.

It is well known that loam, sand and gravel, are comparatively poor conductors of electricity, and experience proves that these materials, in the ordinary modes of fitting the rod, furnish very inadequate means of conveying a heavy charge to the earth.

There is generally no enlargement or extension of surface where the conductor enters the ground, but merely a continuation of the same rod used on the building, thus presenting a very limited surface to partial contact with imperfect conducting materials. It is true a light charge under such circumstance may be safely carried away, but when the cloud furnishes a copious supply of electricity and the point is in a perfect condition, the rod receives the charge with great facility, and if its passage to the earth is opposed by inferior conductors, a disruptive discharge through some part of the building would naturally follow.

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*The defects of this arrangement, so far as the above remarks are designed to be more especially applicable, appear more prominent when other defects exist; when the tip of the rod is imperfect, and the charge enters upon it more or less abruptly, or when the resistance at the earth prevents a free escape of the charge. If the rod were in a perfect condition, in other respects, accidents from this construction would perhaps rarely if ever occur.

If the rod were perfectly insulated it would receive the electricity as before, but in this case the whole charge would leave the rod by an explosive discharge. Again were the rod partially insulated, that is connected with the earth by poor conductors, then a part of the charge would be gradually and silently transmitted through these conductors while the surplus would escape by explosion.

The relative power of the point to receive, and of the material connected with the rod to impart electricity, is a practical question in its bearing on this subject, and worthy of more careful attention than it has generally received.

Where the resistance is very considerable, as it always must be when the rod is merely inserted in the ground as usual, the points receive electricity from the clouds with greater freedom than it is discharged to the earth, and the liability of accident increases in proportion as the receiving power of the rod exceeds the discharging power. A way is opened through the pointed conductor for a free passage of electricity from the cloud to the rod, but the channel of escape to the earth is practically closed.

The rod thus becomes, so to speak, a reservoir of intense electric force, and when the tension is increased beyond certain limits the surplus charge, yielding unwilling obedience to forced circumstances, breaks away from its proper channel.*

In such cases the tip of the rod is often burned or fused, the glass insulators, if such are used, broken and thrown from their places, and frequently the ground where the rod enters more or less disturbed and torn up.

The point of lateral discharge may be determined by various circumstances; — by a short bend in the rod towards the building; by the junction of two or more branches of the rod; by the near approach of a good conductor, as a bell wire, or gas pipe, etc.; stove pipes, iron ware, etc., stowed away near where the rod passes.

These remote influences, however, must not be mistaken for the primary cause of the casuality. In case of the explosion of a steam boiler, under extreme pressure, the slightest irregularity in the uniform thickness or strength of the boiler would be sufficient to determine the point of rupture. So when a lightning conductor is subjected to all the charge it can bear, in consequence of resistance at the earth, a very slight circumstance would turn the balance of force in favor of a lateral discharge.

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*This condition of the rod may be conceived, as somewhat analogous to the hose of an hydraulic engine, with a forcing pump plying at one end while the other end, instead of admitting a free outlet for the water, is firmly closed except some lateral apertures.

There is, indeed, good reason to believe that nine-tenths of the cases noticed, where the rod has failed to accomplish its purpose, are really due to *an overcharge, caused by the resistance of the passage of electricity into the earth.*

In the most severe disasters the rod is invariably found to be very imperfectly connected with the ground, being usually much oxidated, and often extending not more than two or three feet into dry earth, or into sand or gravel nearly dry, by which its conducting communication with the ground is almost entirely destroyed.

But the general effects are observed to be less and less marked, as the condition of the rod is improved and resistance to a free exit of the charge diminished.

There are three kinds of rods very common in New England, viz.: Lyon's Patent Copper Rod, the North American Lightning Rod—galvanized iron, and the Quimby Rod, made of small nail rods in their rough state.

Perhaps a less proportion of serious accidents have occurred with Lyon's rod than with either of the others mentioned, yet more than eighty cases of this rod have been reported from Worcester county alone, where slight damage occurred, or more or less evidence appeared that a charge had passed the rod.

Sometimes the scorching or burning of leaves and grass near the rod would be the only traces of electricity visible. In other cases the ground about the rod would be more or less disturbed and torn up, or the house perhaps slightly injured by a charge passing on to the sill, tearing off some clapboards, splitting the timber, and finally disappearing in the cellar or making its escape outside through a pool of water left by the recent shower.

Such phenomena are of very frequent occurrence, and clearly point to the same ultimate cause of disaster—the ground resistance.

In these cases the rod seemed to perform its functions so far as it could. The charge was conveyed from the clouds *to* the earth but was arrested in its progress *into* the earth, and in forcing a passage to better conductors produced the effects observed.

The tendency of a charge to leave the rod is greater at or near the point of greatest resistence, and the various effects of an overcharge, so very generally exhibited at the lower portion of the rod, sufficiently indicate the primary source of failure. While it is quite unnecessary to detail individual cases for the sake of farther illustration, a single instance of remarkable mechanical effect upon the rod may be briefly stated.

Lyon's patent consists of a copper ribbon so folded or crimped that the cross section forms an *S*. The rod is then twisted once in twelve or fifteen inches in order to give it greater firmness.

In the summer of 1859 this rod was placed upon a new house in North Brookfield, Mass., and was terminated in the embankment formed by sand and gravel thrown out of the cellar, but was not carried deep enough to reach the original soil. During the summer this gravel, so far as the rod penetrated, became very dry, and in this condition the rod was subjected to a severe charge of electricity. The consequence was the twist was completely taken out of the rod throughout its entire length, and the folds or flanges brought firmly together as if by the force of a hammer or the pressure of heavy rollers. The charge escaped where the rod entered the ground, throwing up large quantities of dry earth and making a deep furrow some fifteen or twenty feet in length, as if a large plow had passed through the ground. The house remained uninjured, no part of the charge having left the rod till it reached the earth. This indeed is an extreme case, and so far as I know unparalleled in some of its effect, yet it is but a more forcible illustration of the point in question—*the ground resistance.* Here is the main idea designed to be brought out in this part of my paper, and the prominent cause, no doubt, of the numerous casualties so dishonorable to the confidence and good faith which lightning rods should justly merit.

It now remains to consider the best means of removing the "cause of the failure of lightning rods." This will form the subject of another paper.

2. CONDITIONS OF A PERFECT LIGHTNING ROD. By JAMES BUSHEE, of Worcester, Mass.

WHILE considering the defects of a lightning rod in a former paper, the necessary conditions of a perfect security have been in some degree anticipated.

A rod performs its functions when it conveys the heaviest charge from the cloud to the earth without sensible effects; but in order to remove all liability of accident it should be capable of doing more than this.

No machine can be worked to its utmost capacity without hazard. The rod should always have some working capacity in reserve. The whole charge ought to pass to the earth with such perfect freedom as to avoid high intensity in any part of the rod, thus rendering a lateral discharge impossible, or extremely improbable.

If the earth were a perfect conductor of electricity nothing more would be necessary to secure the requisite conditions than simply to connect the rod with the ground. But since there is a wide contrast between the conducting power of the earth and that of the rod, and since this affords sufficient cause, as proved by observation and experiment, to obstruct and divert the charge, or a portion of the charge, from its proper channel, it follows that the elements of a perfect rod can only be secured by removing all obstructions from the direct pathway of the charge.

While absolute perfection is doubtless, from the nature of the case, impossible, a near approximation is easily attainable, simply by taking advantage of the extensive ranges of metallic gas pipes and water pipes, with which our cities and large towns are supplied. These, no doubt, afford the best means at command, of forming a perfect connection with the ground, and of placing the rod in a condition to perform its proper functions. And this can be done without the least possible injury to the pipes or danger to the persons connected with them. A good rod in proper contact with such pipes freely imparts to them the most powerful charge, which becomes highly diffused as it expands over an extended range of surface contact, where the electricity easily makes its escape into the earth, thus restoring equilibrium with so little resistance, that the desired object may be regarded as completely attained, so far as all practical purposes are concerned.

Since accidents, in relation to these pipes, have sometimes occurred from lightning there seems to be a strong prejudice, in the minds of some, against connecting the rods in this way. Such prejudice, however, appears to arise from not making proper distinction between a gradual and silent discharge through the medium of a pointed conductor, and a sudden or disruptive discharge attended by explosion, as when, in popular language, lightning is said to "strike" an object.

All the cases which have come to my knowledge where the pipes have been damaged or persons injured, are those of *disruptive discharge*, in which the pipes were struck when the whole charge, after passing explosively through some non-conductor, rushed upon the pipes at once, producing widely different results from anything ever observed in a gradual discharge through the agency of points.

The effects of a disruptive discharge upon the pipes may be various, according to circumstances. The joints, if connected by an inferior conductor, as lead for instance, may be injured in consequence of sudden resistance,* while a portion of the charge, perhaps, not having time sufficient for dispersion and escape, flashes up the gas burners in the immediate vicinity, with sufficient force, perhaps, to give severe or even fatal shocks to persons near them.† But nothing of this kind can possibly occur when the charge is received through a pointed conductor properly connected with the pipes.

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* A case of this kind occurred at New Haven a few years since, and noticed by Professor Silliman at the Springfield meeting of this Association.

The joints of these pipes were made tight by sheet lead, which was melted out for a considerable distance by a shock of electricity.

† The rector of St. James Church, Bernon Smithfield, R. I., received a shock from the gas-burner, while sitting in his study, July, 1866, which caused his death a few months afterwards.

The church was near the rector's house, and the lightning rod attached to the steeple terminated in nearly dry sand or gravel. A heavy charge passed down the rod to within about ten feet of the ground, when a lateral discharge was forced through a portion of the building to the nearest gas-pipe, producing much damage to the house and the other effects above mentioned. Also several other persons in the different neighboring houses felt more or less of the shock at the same time. Had the rods of the church been connected directly with the gas-pipes I believe the charge would have been carried off with perfect safety to all, and no one would have experienced any sensible evidence that a charge had passed the rod.

In the former case the charge bursts from the cloud at once and dashes upon the object, as it were, with concentrated force, producing the well known effects of a "stroke of lightning."

In the latter, like a continuous stream of water from a fountain, the cloud pours out its electricity upon the rod, gradually from which it is promptly conveyed to the earth as harmlessly as it was received. When a mill-dam, confining a large pond or reservoir, suddenly breaks away the water rushes out with great violence, overflowing the banks of the stream, carrying off bridges, and sweeping away everything in its course.

This is analogous to a disruptive discharge of electricity. But when the reservoir is drawn off *gradually*, through a proper gateway, the water is confined within the banks of its own natural channel, and quietly pursues its course to the ocean. This resembles a gradual discharge of electricity by a pointed conductor, when the long ranges of metallic pipes serve as safe channels of conveyance into the earth. And we have no more real cause to apprehend danger in one case than in the other.

When such pipes are not accessible, a well, spring, or permanent stream of water affords, perhaps, the next best means of forming a connection with the ground. Water furnishes a much more perfect contact with the rod than earth and gravel, and being a much better conductor than these, it is usually regarded as a safe and reliable mode of applying the rod, to terminate it in a well or spring of water. And this idea is doubtless correct in general, but a well may be so situated on a bed of clay, or in a ledge of rock, that resistance would sometimes be sufficient to cause lateral discharge. It is to the difference between the receiving power and the discharging power of the rod that we are to look for accidents, rather than to the absolute conductivity of the rod as compared with water or other substances with which the rod may be in immediate contact.

The rod may sometimes be connected with a good conductor, which may itself be partially insulated from the general conducting medium of the earth by certain geological conditions.

That a lightning rod will receive a charge of electricity with greater facility than a well of water — under the circumstances mentioned, disposes of it — seems to be proved by the fact that a portion of the charge which had descended the rod to the water, has been known to pass up the lead pipe of the pump into the house and do serious injury.*

It would not always be safe, therefore, to terminate a lightning rod in a well which is connected by metallic pipes with the domestic departments.

A common water cistern also furnishes an unsafe mode of terminating the rod, since the brick and cement ordinarily used offers very considerable resistance to electricity. It is for this reason, no doubt, that cisterns are frequently exploded by a charge of electricity communicated through metallic water pipes connecting the eave trough with the cistern.

When neither of these modes of connection is practicable, something more is necessary to insure safety than the very common way of simply inserting the rod a few feet into the ground, which often becomes very dry during the heat of summer, the time when thunder storms are most frequent and protection the more needed.

Yet it is probably true that three-fourths, if not seven-eighths of the lightning rods in the country terminate in this manner.

When we consider the great want of fidelity, and of a thorough practical knowledge of the subject, so often manifested on the part of the agents or contractors, and the equally apparent want of care and attention on the part of those whose deepest interest is involved, it is not surprising that the record of casualties in Worcester county discloses the remarkable fact that *a large majority of the buildings damaged by lightning are those having rods attached to them.*

So little attention has generally been given to the proper connection of the rod with the ground, so little importance attached to the necessary conditions upon which the efficiency of the rod depends, the free exit of the charge, that instances are not wanting where rods have been erected upon public buildings without the least apparent regard to the conducting power of the materials with which the rod was connected, and with as little thought of the means by which it was to fulfil its proper functions.*

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*The editor of the Woonsocket Patriot (S. S. Foss), states, that the lightning rods of his house run into a well in the cellar, which is located on a ledge of rock, and in the summer of 1868, during a violent thunder storm, one of his domestics received a severe shock from a pump connected with the well by lead pipe. He also states that on examination he found the water low in the well, but the rod extended below the surface of the water some distance at the time of the accident.

The numerous accidents which are constantly presenting themselves, where rods are concerned, sufficiently indicate either a very mistaken idea of the necessary conditions of safety, or an unpardonable neglect in carrying out those conditions.

I have sometimes found but one small rod connecting the roof of a dwelling house with the ground, and that extending only two or three feet into nearly dry gravel.

In such a case the rod is worse than useless; for instead of protection the most effectual means are unwittingly used to invite into the house the first charge of electricity that chances to pass the rod.

The various kinds of soil with which the rod is liable to be connected are widely different in conducting capacity, and in deciding the reliability of the rod it becomes important to determine the conductivity of the ground as modified by geological character and physical condition; and this may be easily done so far as it practically affects the object of the rod by measuring the resistance the earth offers to the passage of an electric current through the rod after it is placed in position.

But probably no kind of soil, even under the most favorable conditions, possesses sufficient conducting capacity to insure safety while in the ordinary state of moisture, and simply in contact with a small rod. I repeat then some other course must be adopted;. and here I have nothing better to offer than to urge the necessity of carrying out in general practice the directions usually given by good writers on the subject, but which are almost universally neglected in this country,* viz.: to enlarge the surface of the rod in the ground by attaching to it a plate of copper which should extend to a sufficient depth to reach permanent moisture and then be surrounded by a liberal quantity of fine charcoal which is a good conductor.

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* When one of the largest churches in this city was first furnished with lightning rods, the main rod attached to the spire was allowed, it is said, to terminate in a boulder of granite, in which a hole was drilled for the purpose. This was done with the impression, if I mistake not, that the solid rock would be more than a "*match*" for the lightning.

For convenience the plate may be turned out from the building horizontally to any distance it may be found necessary. No definite directions of general application can be given as to the size of the plate or its depth below the surface, since the circumstances are so very different in different localities. What would be entirely sufficient for one place would not answer for another. The capacity of the plate and connection with moisture should be such as to remove all undue resistance, and this must be determined experimentally for each particular locality. In this arrangement the deficiency of conducting power is compensated by increasing the surface contact with the ground, on the principle that a greater number of poor conductors may be equivalent in efficiency to a less number of better conductors.

But buildings may sometimes be located where circumstances of some nature render it impracticable to carry out any of the methods proposed so as to form a proper ground connection. In such cases points may be used as an efficient means of relieving the rod so as to prevent a disruptive discharge. The rod may be furnished with several short points directed from the building, and its lower extremity connected with a copper ribbon which should have all the advantage of ground connection circumstances will allow, and extend considerable distance from the building (twenty to forty feet), terminating in a short rod with points at top and also near the ground. These lower points serve the double purpose, first, of exhausting surcharged atmosphere near the surface, and second, of dissipating and weakening a charge from the clouds.

I see no reason to doubt that any portion of the charge which may not have been conveyed into the earth by conduction would be dispersed by convection without surcharging the rod. The objection may here arise, that the lower points by imparting the electricity to the atmosphere do not effect a positive discharge — that the charge is merely transferred from one locality to another, even nearer the house than before, and perhaps exposing it and other buildings in the vicinity, to still greater danger.

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* The prevalent defective mode of making the ground connections, probably obtained on the score of *economy*; but that is very poor economy which neglects the absolute conditions of safety and incurs the first expense of the rod merely to expose the house to greater danger than before.

But I think it must be conceded that such a transfer could hardly be made without, at least, a decided loss of electric force. Indeed every leaf twig and blade of grass, within the influence of the charge becomes so many little lightning rods to convey it into the earth.

Furthermore should a surplus, from any cause, tend to preponderate in the manner supposed, the very points which imparted it would be as ready to receive and convey it through the rod into the earth, or at least a portion of it, while the residual may ascend the rod and be imparted to the atmosphere above, and possibly several such transfers may take place even within a very short interval of time, yet weakening, in force, at every vibration, until compensation should be restored.

In regard to houses with metallic roofing, it is supposed by some that they are not so liable to be struck by lightning as other houses under similar circumstances — that such a roof serves, in some way, as a shield of protection against the effects of lightning, but no good reason appears for such a supposition. It is very probable, however, that a charge may sometimes be received upon the highest parts of the roof as it often is upon telegraphic wires, and be again diffused into the atmosphere through the sharp corners and edges of the lower portions of the roofing. Indeed if the usual points were erected upon such a roof and the eaves furnished with a number of good points there is little reason to doubt that they would prove a reliable protection to the building.

But since houses with such roofing have been sometimes struck by lightning and seriously damaged, one or two cases having occurred within my knowledge,* where the roof was literally destroyed; it would be well to take all possible precautions for safety. Good points should be erected on the most prominent parts of the house, particularly upon the chimneys and well attached to the metallic surface.

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* In the summer of 1859 the house of Mr. Muzzy of Spencer, Mass., was struck by lightning and much injured. The house was without rods and the roof covered with tin. The charge entered the chimney through which it passed outward on to the roof, perforating and tearing up the tinning so generally that it was necessary to replace it by an entire new covering.

In making the ground connections, however, it is sufficient to affix the rods to the corners or edges of the roof, carrying out the directions already given in their terminations with the ground. Whenever proper contact cannot be made so as to remove resistance discharging points should always be used.

In concluding this paper it is proper to say that I have attempted to consider the subject of lightning rods simply in its practical bearing. It has been not so much my object to present new facts or theories, as to urge a better application of principles well known,—to point out some of the most prominent defects in the construction of rods, and finally to present such obvious means of removing these defects as observation and experiment seemed to suggest. Neither have I pretended to give a full and detailed description of the rod. Nothing has been said of its height above the roof; the number of points at the tip; the mode of insulating and fastening to the building; of the general style, form, size or material, simply because most of these are deemed of minor importance, and the great defects, which it has been the chief object to bring out, are not here found.

V. CHEMISTRY.

1. On Molecular Perturbations.* By Gustavus Hinrichs, of Iowa City, Iowa.

Any series of compounds of like structure may be written

$$RM \qquad (1)$$

where M represents that part of these compounds which is common to all members of the series, while R represents the *radical* changing from one compound to the other. Thus in the nitrates of monatomic radicals

$$R'O_3N$$

we have

$$R = R' \text{ and } M = O_3N.$$

By an application of the general mechanical principles of the fourth section of my *Atomechanik* (1867), the *normal form* of the atomic structure, RM, can be determined. Already in that work it *has* been done for certain series, like the Tritoids AB_2, the Deltoids, AB_3C, etc.

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* Also No. 3 of my *Contributions to Molecular Science.*

Let the axes of this normal form, or the *normal axes* of the compound atom, RM, be

$$x : y : z \qquad (2)$$

These *normal* axes correspond to a given ideal case; just as the *normal* elliptical orbit of the planets corresponds to the ideal case of but one planet encircling the sun, and both bodies being infinitely small in comparison to their mutual distance. The normal axes correspond to *mutually equal* atoms (*Atomechanik*, §. 231 and §. 233).

Accordingly there always must be a certain value of R for which the given M will produce exactly the normal axes in the compound RM. Let this value of R be represented by r. Then the deviation of the *actual* axes

$$a : b : c \qquad (3)$$

from the normal axes must be proportional to the difference $R—r$. These deviations we call *molecular perturbations*, and denote them *in general* by π; in the direction of x, y, z, they are denoted, respectively, by ξ, ζ, ζ.

If, then, k be a *constant*, mainly determined by M, we shall have, in general, the molecular perturbation

$$\pi = k\,(R - r) \qquad (4)$$

A difference, $R - r = 1$, gives $\pi = k$; that is k *is the perturbation due to each unit in the atomic weight of the disturbing element* R.

From this it is also apparent that the greater the disturbed mass M the smaller must be the coefficient k; or, approximately for comparable cases,

$$k = U - VM \qquad (5)$$

where U and V are constants.

It is admitted that the preceding deductions are in a more popular form; those who ask for more formal mathematical developments are referred to the latter part of this paper. In order not to repel the chemist and mineralogist, the more special developments were deferred to this place.

The value of r is also determined mainly by M. Thus if RM represents compounds, resulting by synthesis of R and M under great evolution of heat, a considerable attraction or affinity between R and M is manifest. Accordingly r will be negative, indicating that it would require a *repulsion* of the numerical value r to produce the normal equilibrium or form.

We may now proceed to the application of these principles.

I. TITANOID DIOXIDES, TtO_2.

Referring to contribution No. 1 (p. 13)* for the details, we have, agreeable to (4):

$$\zeta = -0.001\ [Tt + 130] \qquad (6)$$

which gives very good results. Accordingly the attraction between the titanoid, Tt, and the two atoms of oxygen is so great that a repulsion of 130 ($r = -130$) would be required to produce the normal form.

The normal form of these titanoid dioxides is

$$x:y:z = \sqrt{3}:1:\sqrt{3}$$

(See Contrib. No. 1, p. 11, or Report Chicago Meeting, p. 217). The perturbation ζ is in the axis z, which passes through the atom Tt and stands at right angles to the middle of the line joining the two atoms of oxygen. The observed axes a, b, c, tabulated at the close of this paper, give the *observed* perturbations by means of

$$a = x + \xi \qquad b = y = 1, \qquad c = z + \zeta \qquad (7)$$

For these dioxides the values are

	Tt	ζ *calculated.*	*observed.*
Cassiterite	$Sn = 118$	-0.248	-0.245
Rutile	$Ti = 50$	-0.180	-0.180
Zircon	$\frac{Zr+Si}{2} = 59$	-0.189	-0.171
Pyrolusite	$Mn = 52$	-0.182	-0.180

Although manganese is not a titanoid, the perturbation of pyrolusite very nearly agrees with that calculated for titanoid-dioxides. The calculated value for Zircon differs considerably from observation; it will necessarily depend upon the exact formula of the mineral, while the calculated value above given is obtained on the hypothesis of an equal number of atoms of zirconium and silicon. Thus

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* Report of Chicago Meeting (1868), p. 221.

$$\frac{Zr + 3\,Si}{4} = 43.5$$

would give — 0.178 instead of the — 0.171 observed.

II. ARAGONITOID CARBONATES.

The three atoms of oxygen in the Carbonates $R'' O_3 C$ determine the plane $y z$, the axis z passing through one of these atoms, while y is at right angles thereto in the centre of gravity of the triangle formed by the three oxygen atoms. This triangle is nearly or exactly equilateral, giving the normal axes

$$y : z = 1 : \sqrt{3}$$

The axis x is at right angles to both, and passes in one direction (say upwards) through the Calcium atom, in the other direction through the Carbon atom, so that the angle

$$Ca - O - C \text{ is } 90^\circ$$

or very nearly so. Thus $x = z = \sqrt{3}$. See *Atomechanik*, §§ 303–306.

The observed values of a, b, c, tabulated at the close of this paper, give by (7) the following values of the *perturbation* ζ *in the oxygen plane* after axis Z.

	Xa	ζ *calc.*	ζ *obs.*	*calc.–obs.*
Aragonite	$Ca = 40$	-0.127	-0.1266	0.000
Strontianite	Sr 88	-0.085	-0.090	$+0.005$
Witherite	Ba 137	-0.040	-0.040	0.000
Cerusite	Pb 207	$+0.024$	-0.093	$+0.117$

The calculated values have been obtained according to (4) by

$$\zeta = 0.0009\,(Xa - 181) \qquad (8)$$

It is seen that lead, not being a calcoid, but member of the genus cadmoids, the corresponding carbonate does not agree in its perturbation with the calcoid-carbonates, thus proving that the cadmoid-atoms, in form or structure, essentially differ from the calcoid atoms, a result which must be admitted also on other grounds. Thus the calcoids are non-volatile, while the cadmoids are comparatively very volatile metals.

Applied to the perturbation of the *vertical prism* the general law (4) gives

$$\pi = 0'.72\ (Xa - 200) \qquad (9)$$

		Xa	τ *calc.*	τ *obs.*	*calc.-obs.*
Aragonite	$Ca =$	40	$-114'.2$	$-115'$	$+\ 0'.8$
Strontianite	Sr	88	$-\ 80'.6$	$-\ 80'$	$-\ 0'.6$
Witherite	Ba	137	$-\ 44'.4$	$-\ 45'$	$+\ 0'.6$
Cerusite	Pb	207	$+\ 6'.$	$-\ 83'$	$+89'.$

The normal angle between the vertical prisms and the plane yx is $p = 60°$. The above minutes represent the derivation of the observed values from this angle of 60°.

The value of r is *positive* in both formulæ (8 and 9) but not quite identic, although it ought to be so. It requires an attraction of 181 according to (8), and of 200 according to (9), to reduce the perturbation in the oxygen section to nothing; that is, to make the aragonitoid hexagonal for the calcoid-elements Xa.

I think that this is in accordance with chemical principles. The oxygen of the electro-positive $Xa\,O$, being in the same plane with the oxygen of the electro-negative $C\,O_2$, exerts a repulsion on the same, equivalent to $r = 181$. Compare §315 of *Atomechanik* on this point. In the hexagonal Calcit-forms, the $Xa\,O$ and $C\,O_2$ exist together as *one* $Xa\,O_3\,C$, and accordingly $\zeta = o$. Herewith harmonizes the fact, that according to *Favre* and *Silbermann* (1852), each gram of aragonite sets free 39.1 calorics when being converted into calcite; or each atom $Ca\,O_3\,C$ sets free 3910 calorics. Compare also VI. in Contribution 5.

III. CALCITOIDS.

Of the carbonates, only magnesite and smithsonite belong to the same genus. This is sufficient to determine the two constants in (4), but not enough to give any control. The three aragonitoid carbonates have, however, given that control, so that we may apply (4) also on the calcitoids.

Indirectly we shall have a very excellent control in the values of the constants thus determined; for they must agree with the known chemical properties of the elements.

For the calcitoids the horizontal perturbations ζ is zero; the vertical ξ is for the cadmoids.

$$\xi = -0.1092 - 0.000161\,K\delta \qquad (10)$$

or

$$\zeta = -0.000161\,[K\delta + 678] \qquad (11)$$

The same perturbation is, for the angle R of the rhombohedron, the normal being 104° 29′ (Atomech., §307)

$$\rho = +0.'25\ (K\delta + 698) \qquad (12)$$

The observed values are:

	$K\delta$	R	ρ	ξ
Magnesite	Mg, 24	107°.29	$+180'$	-0.1131
Smithsonite	Zu, 65	107°.40	$+191'$	-0.1197

The value of $r = -678$ or -698 indicates an *attraction* of nearly 700 between RM, or a repulsion of this magnitude is required in order that $K\delta\,O_3\,C$ may have the normal form, the rhombohedron $R = 104°\ 29'$. Now this is exactly what might have been predicted, since the cadmoids have not only a great affinity for O, but also because their atomic weight is in excess of both O and C. Thus, in Smithsonite, the amount of matter in any horizontal is equivalent to $2\,O = 32$, but in the vertical it is $C + Zn = 12 + 65 = 75$, or more than twice as much. Since there is no chemical repulsion between Carbon and the Cadmoids, this preponderance of matter in the vertical axis must contract the same, as observed.

The two sulpho-salts $Ag_3\,S_3\,\Phi$ of this form give for (4):

$$\xi = -0.00066\,[\Phi + 114] \qquad (13)$$

and

$$\rho = +1'.15\,[\Phi + 98] \qquad (14)$$

the observed values being

	Φ	R	ρ	ξ
Proustite	$As = 75$	107°48′	$+199'$	-0.125
Pyrargyrite	$Sb = 122$	108°42	$+253'$	-0.156

The normal rhombohedron of 104° 29′ will thus belong to a phosphoid Φ of the atomic weight $r = -98$ or -114; that is a *repulsion* of from 100 to 120. This is also in accordance with the chemical properties of the elements here involved. For the phosphoid and silver, here in the axis X, very readily combine, thus indicating an attraction of Ag_3 or Φ, so that for any Φ it would require a *repulsion* to produce the normal form. The same follows by considering the mere mass in the different directions; thus along Z and Y we have the equivalent of $2S = 64$, but along X we have $3Ag + \Phi = 324 + \Phi$ which for Proustite is 399; for Pyrargyrite 446, that is from 6 to 7 times as much!

IV. CALCOID SULPHATES.

In the sulphates SO_2 exists as such, forming, like all compounds of the formula AB_2 or $A \left\} {B \atop B'} \right.$, an equilateral triangle, either exactly or nearly so. The axis Z is laid through S, and Y through the two atoms of oxygen of SO_2. The axis X is at right angles to these, and contains the other two oxygen atoms of the sulphates. As demonstrated in another place, the *normal* axis of the sulphates $R'' O_4 S$ are

$$x : y : z = \sqrt[4]{3} : 1 : \sqrt[2]{3} \qquad (15)$$

The perturbations most directly due to the different radicals are those in the axis of Z; for the radical R'' is directly opposite to the sulphur-atom, S. The normal vertical prism, parallel to the axis X, is nearly *hexagonal;* the normal angle between the vertical face and the plane XY, is 60°; the deviation of the crystal from this angle we call π. The observed values then give for these perturbations for the calcoids:

$$\zeta = -0.0008\,[Xa + 20] \qquad (16)$$
$$\pi = -0'.7\,[Xa + 20] \qquad (17)$$

NAME.	Xa	ζ calc.	obs.	π calc.	obs.
Anhydrite	Ca 40	−0.048	−0.048	− 42′	− 43′
Celestite	Sr 88	−0.086	−0.089	− 75′.6	− 80′
Barite	Ba 137	−0.126	−0.122	−109′.9	−110′

Accordingly, $r = -20$ in both of these equations. That is, it requires a repulsion of 20 to produce the normal hexagonal form of the vertical prism here under consideration. This is again in harmony with the atomic structure and the known affinities. For in the axis Z we have $S+Xa=32+Xa$, reaching from 72 (for *Ca*) to 169 (for *Bà*), while in the axes X and Y there are only 2 atoms of oxygen, weighing 32. Hence a greater attraction in the direction of the Z axis, or a shortening of the same (ζ negative, r negative). Besides, we know that the calcoids have a considerable affinity for sulphur — which, therefore, increases the perturbation due to the mass merely.

This law has been extended to Selenates, Chromates, Perchlorates, Permanganates (see Synopsis of new Memoirs on *Atomechanics*, published July, 1868). Here it may be sufficient to give the observed values of the angular perturbation π, or the deviation of the vertical prism found forming 60° with the vertical plane xy.

Name.	*Formula.*	π	
Anglesite	PbO_4S	— 81′	
Barite	BaO_4S	—110′	mean — 77′
Celestite	SrO_4S	— 79′	
Anhydrite	CaO_4S	— 42′	
Permanganate	KaO_4Mn	— 92′	Mitscherlich.
"	"	— 80′	Groth.
Perchlorate	KaO_4Cl	— 86′	Groth.
"	"	— 83′	Mitscherlich.
Olivenite	Mg_2O_4Si	— 24′	Haidinger.
Phenacite	Be_2O_4Si	— 0	——
Willemite	Zn_2O_4Si	+ 0	——
Normal form	AB_4C	0	——
Sulphate	Ka_2O_4S	+ 12′	Mitscherlich.
Selenate	Ka_2O_4Se	+ 12½	"
Chromate	Ka_2O_4Cr	+ 20′	"
Manganate	Ka_2O_4Mn	+ 35′	"
Ammonium Chloro Zincate	$AmCl_4Zn$	+ 40′	

The most interesting fact exhibited in these perturbations is the change of π by the doubling of *Ka*. A mere increase in weight of *Ka* in the permanganate KaO_4Mn would increase the negative value of π. But the addition of another atom of potassium, producing the Manganate Ka_2O_4Mn, does *not* increase the perturbation in the same direction, but changes its sign. This indicates a slight but real repulsion between the two atoms of potassium, in harmony with the electro-chemical views.

V. PERTURBATIONS AND TEMPERATURE.

On page 43 of *Atomechanik*, the influence of temperature on the molecular perturbations has been investigated, and the results exemplified by means of *Fizeau's* observations then published. In Pogg. Ann. 1868, p. 135, we find additional observations of *Fizeau*, so that we now can continue the investigation of the subject.

In the following determinations of *Fizeau* the coefficient of expansion for one degree centigrade (at the temperature of 40°), is in the direction of (Fizeau's) vertical axis a, at right angles thereto a'; and the change of either for each degree of temperature is Δa and $\Delta a'$. For the sake of simplicity we refer all of these numbers to the original length of *one million units;* then $a = 0.00001911$ of *Fizeau* for Fluorspar (the expansion of the length 1) becomes here $a = 19.11$ (the expansion of 1,000,000).

TRITOIDS, AB_2.

$CaFl_2$, Fluorspar $a = a' = 19.11$
Fe_2S_2, Pyrite $a' = a' = 9.08$
Cu_2O, Cuprite $a = a' = 0.93$
" $\Delta a = \Delta a' = 0.0210$
} in all directions.

	a	a'	Δa	$\Delta a'$
Quartz, SiO_2	7.81	14.19	0.0177	0.0238
Rutile, TiO_2	9.19	7.14	0.0225	0.0110
Cassiterite SnO_2	3.92	3.21	0.0119	0.0076
Zircon (Si, Ti) O_2	4.43	2.33	——	——

DELTOIDS, AB_3C.

For these a is the expansion in the direction of our axis X, or a, a' in the direction Y or b, and a'' in the direction Z or c.

	a	a'	a''
Calcite	+ 26.21	— 5.40	— 5.40
Araganite	+ 34.60	+ 10.16	+ 17.19

These values must be referred to $b = 1$, by subtracting the coefficient after this axis from each of the other coefficients; the values thus obtained express the relative expansion in these axes. It must also be borne in mind that these coefficients refer to our X, Y, Z, in the following manner:

	X	x	Y	y	Z	z
Quartz	a	1	a'	$\sqrt{3}$	a'	$\sqrt{3}$
Rutile	a'	$\sqrt{3}$	a	1	a'	$\sqrt{3}$
Cassiterite	a'	$\sqrt{3}$	a	1	a'	$\sqrt{3}$
Zircon	a'	$\sqrt{3}$	a	1	a'	$\sqrt{3}$

The values of our *normal axes* x, y, z, have also been added. For details see *Atomechanik*, p. 34, or Contributions to Molecular Science, No. 1 (Report Chicago Meeting, p. 217).

This gives our $y = b = 1$, with no relative expansion and no perturbation. For the other axes we obtain: $\delta\xi$ as the relative coefficient of expansion after X (for each million of *units* of length), $\delta'\xi$ the variation of $\delta\xi$ for each degree; and $\delta\zeta$, $\delta'\zeta$ for the axis Z. The results are contained in the following table:

THE TESSERAL TRITOIDS.

Fluorspar, *Pyrite* and *Cuprite*

have $\xi = \zeta = o$; and also $\delta\xi = \delta\zeta = o$.

THE HEXAGONAL TRITOID.

Quartz

$x = 1.0000$ $\qquad$ $z = 1.7320$

$\xi = +0.099$ $\qquad$ $\zeta = 0.0000$

$\delta\xi = -6.38$ $\qquad$ $\delta\zeta = 0.0000$

$\delta'\xi = -0.0061$ $\qquad$ $\delta'\zeta = 0.0000$

THE QUADRATIC TRITOIDS

have $x = z$ and also their variations equal, so that *they remain quadratic*. We give only the values for x:

	$x = z = \sqrt{3}$	$\xi = \zeta$	$\delta\xi = \delta\zeta$	$\delta'\xi = \delta'\zeta$
Rutile	1.7320	—0.180	+2.05	+0.0115
Cassiterite	1.7320	—0.245	+0.71	+0.0043
Zircon	1.7320	—0-171	+2.10	+ ——

THE HEXAGONAL DELTOID.

Calcite

$X = \sqrt{3} = 1.7320$ $\qquad$ $z = \sqrt{3} = 1.7320$

$\xi = -\ 0.0235$ $\qquad$ $\zeta = 0.0000$

$\delta\xi = +\ 31.61$ $\qquad$ $\delta\zeta = 0.0000$

The Rhombic Deltoid.

Aragonite $X = \sqrt{3} = 1.7320$ $z = \sqrt{3} = 1.7320$
$\xi = + \ 0.0035$ $\zeta = - \ 0.1266$
$\delta\xi = + \ 24.44$ $\delta\zeta = + \ 7.03$

These observations show:

1. That *when the molecular pertubation is zero, it remains so.* In other words, the normal form is not changed by an increase of the temperature. — Examples: the tesseral tritoids, also ζ in quartz and calcite.

2. That *the molecular perturbations are diminished by increase of the temperature.* In other words, the actual form approaches the normal form when the temperature is raised. Examples are quite numerous in the above observations; they are indicated by the opposite sign of the perturbation and the coefficient of expansion.

3. The expansion of aragonite in the direction of the vertical axis X is an exception to the preceding rule; for ζ and $\delta\zeta$ have the same sign, so that the actual form passes farther and farther from the normal as the temperature is raised. This proves that the atoms in aragonite are not in a stable equilibrium; and in fact, by heating a crystal of the same, it suddenly changes from aragonite to calcite at a certain temperature, developing 3910 calorics (for each atom of C_2O_3C) in the process (*Favre* and *Silbermann*, 1852).

Thus we have brought all of the preceding determinations of the expansion of crystals under the one general law; *diminution of the molecular perturbation to zero*, or approximation of the crystal to the normal form.

The preceding, we hope, is sufficient to show that the *molecular perturbations* are a reality, as well as the cosmical perturbations of astronomy. However incomplete and imperfect our knowledge of this subject may be at present, we deem it sufficient to invite to farther research. While we believe the *general law* (4) of molecular perturbations to have been sufficiently proved by observations, we admit that the precise value of the constants k and r is at present only imperfectly determined by observation, and only in a very general way by theory.

The exact theoretical determination of these constants is a mechanical problem, the solution of which depends as much upon the constitution and form of the atoms of the so-called chemical elements, as does the theoretical determination of cosmetical perturbations on the structure, form and mass of the cosmical bodies.

APPENDIX.

That the law (4) is in fact a first approximation is proved by the following preliminary analysis of this problem, referred to in the first part of this paper.

Let the substance under consideration be a ternary, composed of the element-atoms A, B, C. To simplify the subject, let the compound be a deltoid, AB_3C.

The actual axes of this deltoid we call a, b, c; the line joining the two atoms A and C, being taken as X-axis or its value $= a$.

If now, without changing anything, the atoms A and C were made equal to B, the axes a, b, c, would become x, y, z, *the normal axes*. Leaving C, but substituting only the radical $A = R$, a certain value $R = r$ must likewise produce the normal axes x, y, z; the corresponding compound being $r\ B_3C$. Accordingly the force producing increments ξ, y, ζ, on x, y, z, is *zero* for $A = R = r$.

Now, let the force between A and C be represented by the function $\Psi\,(A, C)$; similarly that of A and B by $\varphi\,(A, B)$, between C and B by $\varphi'\,(C, B)$, and the repulsion between the like atoms B by $p\,(B, B)$. Into all of these the actual axes a, b, c enter as variables. The resulting force, therefore, will be

$$F\,(A', B, C) = \Psi\,(A, C) + \varphi\,(A, B) + \varphi'\,(C, B) - p\,(B, B), \tag{18}$$

By substituting $A = r + h$ and developing we obtain

$$\begin{aligned} F(r+h, B, C) = K_0 &+ K_1\,(A-r) \\ &+ K_2\,(A-r)^2 \\ &+ K_3\,(A-r)^3 \\ &+ \text{etc.} \end{aligned} \tag{19}$$

where

$$\left.\begin{aligned} K_0 &= \Psi\,(r, C) + \varphi\,(r, B) + \varphi'\,(B, C) - p\,(B, B) \\ K_1 &= \frac{d\Psi\,(r, C)}{dA} + \frac{d\phi\,(r, B)}{dA} \end{aligned}\right\} \tag{20}$$

The functions, Ψ, φ, etc., contain probably only the first powers of the atomic weights; hence K_2, K_3, etc., will be zero, or the squares and higher powers of $(A-r)$ may be omitted.

At the same time we have, according to the definitions given

$$a = x + \xi \qquad b = y + \zeta \qquad c = z + \zeta \qquad (21)$$

(See also 7).

If, therefore, we neglect the square and higher powers of $(A-r)$, we have for a *first* approximation, the normal axes determined by K_0, and the perturbations by K_1. For the perturbations π in *any* direction we shall have an equation of the

$$\pi = K_1 (A-r) \qquad (22)$$

form which is identic with (4). It is evident that K, depends upon the normal axes, x, y, z, and the values of r, B and C. If the form of the functions, as well as the normal axes are known, then K_0 would serve to determine the value of r.

The above formulæ have been simplified by not writing the values of a, b, c, which enter into every one of functions. Since now the law of the variation of these attractions and repulsions in regard to distance and angle (atomicity) is unknown, we may be excused from entering into any farther detail. At the same time it will be admitted, that the only possible solution is based upon an accurate knowledge of the *element-atoms as physical bodies*, such as they are represented in the first section of my *Atomechanik*.

2. On the Classification and the Atomic Weights of the so-called Chemical Elements; with reference to Stas' Determinations. By Gustavus Hinrichs, of Iowa City, Iowa.

Like all other natural objects the chemical elements (so-called) can be classified into *natural* groups,—*Genera* made up of the individual elements as *Species* and *Varieties*. Such a classification was published in 1867 in my *Atomechanik* (§ 17, pp. 7, 8).

The symbol of the *species* is the characteristic letters of the

Latin name of the same, introduced by *Berzelius* in 1815; it has also a *numerical* value, representing the weight of the atoms.

As symbol of the *genus* I introduced the characteristic letters of the *Greek* name of the same, and stated that this symbol represents an *equation*, the numerical value of which for the given variable would be the atomic weight of the species corresponding to that variable.

The theoretical ground of this classification is exposed in *Atomechanik*. We shall here *exclusively* consider this question from a practical and empirical point of view, entirely independent of the pantogen-hypothesis. In this form it has now for two years been presented in my lectures.

I. CLASSIFICATION OF THE ELEMENTS.

This *empirical* classification (in its results *identical* with that of *Atomechanik*) is based mainly on the deportment of the elements toward *heat*. This physical agent being motion, *we accordingly classify the elements in regard to the mobility of their particles (the atoms)*. We distinguish *six* degrees of *fusibility*, *three* degrees of *volatility*, and the *coloration of the flame* for the metals. We retain the general division of the elements in two *orders*, metals and metalloids, based upon the presence or absence of metallic lustre. The above degrees of fusibility correspond very nearly to those of *von Kobell*.

For farther explanation we may refer to the following *table*, merely adding, that the *name* of the genus was taken from the most common or most characteristic element. The semi-barbarous name Sulphoid was chosen, because the more correct Thionoid is not so palpable to students.

GENERAL TABLE OF THE GENERA OF THE ELEMENTS.

Fusibility.	Volatile.	Flame.	Genus. Name.	Genus. Symbol.	Representative Species.
I. **Metals**; having metallic lustre.					
1	exceeding	color	*Kaloids*	Κα	*Ka*
2	very	no color	*Cadmoids*	Κδ	*Cd*
3	slightly	——	*Cuproids*	Κυ	*Cu*
4	not	color	*Calcoids*	Χα	*Ca*
5	not	no color	*Ferroids*	Σι	*Fe*
6 (infus)	not	——	*Titanoids*	Ττ	*Ti*
II. **Metalloids**; not having metallic lustre.					
Triatomic Elements like Phosphorus			*Phosphoids*	Φ	*P*
Di— " " Sulphur			*Sulphoids*	Θ	*S*
Mon— " " Chlorine			*Chloroids*	Χ	*Cl*
Mon— " " Pantogen			*Pantoids*	Υ	*H*

To these genera several others will have to be added; but not until the elements concerned are better known. Of such genera I mention here the Thalloids, *θλ*, Molybdoids, *Μλ*, Hydrargoids, *Υγ* from *Atomechanik*. Beryllium is either the first species of the Ferroids or of the Cadmoids.

The Ferroids are distinguished for their *varieties*. Thus the third species (Iron; Greek *Sideros*) is associated in nature and in its properties with four varieties, which we term the *Sideroids* and give the symbol *Σδ*. They are Chromium, Manganese, Iron (*the* species), Nickel and Cobalt. They form a regular series, connecting Titanium of the Titanoids with Copper of the Cuproids (see Chart). The Rhodoids and Iridoids are not sufficiently known yet. Uranium is associated with Cobalt and the Sideroids, having exactly twice the atomic weight of Cobalt.

The species in each genus are again arranged in the order of their volatility, *or* specific gravity, *or* atomic weight. By printing their symbols at distances from that of the genus, nearly proportional to the atomic weight, we obtain the following chart representing our classification of the elements. A few of the most important elements not embraced in the above ten genera have been added.

HINRICHS' CLASSIFICATION OF THE ELEMENTS.

GENERA.				Species.			
$x =$		1	2	3	4	5	
Υ		*H*					
Κα		*Li*	*Na*	*Ka*	*Rb*		
Χα		—	—	*Ca*	*Sr*	*Ba*	
Κδ		—	*Mg*		*Zn*	*Cd*	*Pb*
Υγ		—	—		—	—	*Hg*
Κυ		—	—		*Cu*	*Ag*	*Au*
Χι			*Al*	*Co* *Ni* *Fe* *Mn* *Cr*	*Rh*	*Ir*	
Ττ		*C*	*Si*	*Ti*	*Pd* *Sn*	*Pt*	
Φ		*N*	*T*	*As*	*Sb*	*Bi*	
Θ		*O*	*S*	*Se*	*Te*	—	
Χ		*Fl*	*Cl*	*Br*	*Io*	—	
Υ	*H*						

That this is a truly *natural classification* is proved by the fact that in this table the elements of like properties, or their compounds of like properties, form groups bounded by *simple lines*. Thus a line drawn through *C*, *As*, *Te*, separates the elements, having metallic lustre from those not having such lustre. The gaseous elements form a small group by themselves, the condensible chlorine forming the boundary. So also the boundary line of the *heavy metals* (specific gravity above five) is a simple line, running between *Kδ* and *Xa*, as far as the break in the vertical columns goes (to *Zn*), then down to *Ti* and through *Se* out between *Te* and *Io*. So also the boundary lines for other properties may be drawn.

Of great practical importance are the lines expressing certain properties of definite compounds. Thus, the solubilities of Ternaries or Binaries in water. The reactions in the wet way (Fresenius). The blowpipe reactions, may be represented on such charts by means of a few simple lines. Such charts have been in use in my laboratory, and were exhibited to the Association — the symbols printed on muslin (size 8 × 6 decimeters) while the other details had been entered by hand. In the lecture room I also have been using a square blackboard of black walnut (one meter each way) with the symbols painted; a chalk line or figure then enters the property dwelt upon by the lecturer.

II. The Atomic Weights.

If we inscribe the atomic weight in the table of elements just given, it will immediately be seen that in each of the columns, marked $x = 1, 2, 3$, etc., comparatively small changes take place. This suggests a *general law, determining the atomic weight y of any species as a function of x for all genera.*

$$y = f(x). \tag{1}$$

Theoretically we may determine the nature of this function in the following manner: if we assume the existence of but one substance (pantogen).

A certain number c of the *mutually equal atoms* of this pantogen may combine, producing an element of the atomic weight $y = c$, that of hydrogen being one. Any two of these new atoms may again combine, giving $y_2 = 2c$. These again combining give $y_3 = 2y_2 = 2.2c$, of which again $y_4 = 2y_3 = 2.2.2c$ would follow. Thus *by simple reduplication* of the original atoms $y_1 = c$, we would obtain atoms of other substances (elements) expressed by the general formula

$$y = c.2^{x-1} \tag{2}$$

All of the elements for which c has the same numerical value would evidently closely resemble one another, or constitute a *genus* of elements. Variation in the value of c would give the different genera.

Another mode of combination in the successive addition of the same c to itself, giving

$$y = c.\,x \tag{3}$$

There are evidently other methods of combination; but those here given are undoubtedly the *simplest possible*, and hence the most probable.

A parallel to the law (3) we have in the hydrocarbons, where the successive atoms of carbon are linked together by means of hydrogen atoms. Accordingly it is possible, and rather probable, that less complex aggregations k of atoms of the primary matter will be required as links to bind together the members c of the atoms y. Consequently a more general form of the preceding laws would be

1. *For Reduplication*:

$$y = c.\,2^x + k \tag{4}$$

2. *For Simple Aggregation*:

$$y = c.\,x + k \tag{5}$$

In their equations k must necessarily be *comparatively small* if it changes with x, otherwise expressive of a terminal common to the genus, it may be even large, as in the Cuproids, Cadmoids and Calcoids. From the observed values of the atomic weights *we may conclude that all the metallic elements, except the calcoides, are formed by reduplication* (4); *the calcoids being formed by aggregation* (5). *The metalloids are formed mainly by reduplication* (4).

This we conclude from the following comparison between the calculated and observed values of the atomic weights. In all of the following tables, the *correction* is to be added to the calculated value in order to give the observed value, taken from Jahresbericht, 1866.

A. METALS.

1. *Genus.* KALOIDS.

$$Ka = 5.2^x + 3\,(-1)^x \qquad (6)$$

SPECIES.	x.	Ka		Correction.
		calc.	obs.	
Lithium	1	7	7	0
Sodium	2	23	23	0
Potassium	3	37	39.1	+2.1
Rubidium	4	83	85.4	+2.4
. . . . . .	5	157	—	—

2. *Genus.* CUPROIDS.

$$K\upsilon = (5.5)\,2^x + 20 \qquad (7)$$

. . . . . .	1	31	—	—
. . . . . .	2	42	—	—
Copper	3	64	63.4	—0.6
Silver	4	108	108	0
Gold	5	196	197	+1

3. *Genus.* CADMOIDS. Omit the constant for $x = 1$ and 2.

$$K\delta = 6.2^x + 16 \qquad (8)$$

. . . . . .	1	12	—	—
Magnesium	2	24	24	0
——				
Zinc	3	64	65.2	+1.2
Cadmium	4	112	112	0
Lead	5	208	207	—1

4. *Genus.* FERROIDS.

$$\Sigma\iota = (6.25).2^x + x\,(+1)^x \qquad (9)$$

——	1	13.5	—	
Aluminium	2	27	27.4	+0.4
Iron	3	53	56	+3
Rhodium	4	104	104.4	+0.4
Iridium	5	205	198	—7

5. *Genus.* TITANOIDS.

$$Tr = (6.5).2^x + x\,(-1)^x \qquad (10)$$

Carbon	1	12	12	0
Silicon	2	28	28	0
Titanium	3	49	50	+1.0
Palladium	4	108	106.6	−1.4
Platinum	5	203	197.4	−5.6

6. *Genus.* CALCOIDS.

$$\begin{aligned} Xa &= 48\,(x-2) - 8 \\ &= 48\ x - 104 \end{aligned} \qquad (18)$$

Calcium	3	40	40	0
Strontium	4	88	87.6	−0.4
Barium	5	136	137	+1

B. METALLOIDS.

For these we have in general

$$\left.\begin{aligned} y &= c.\ 2^x \\ y &= c\ [2^2 + b.\ 2^{x-2}] \end{aligned}\right\} \quad (11)$$

where the upper is to be used for $x = 1, 2$; the lower for $x = 3$, 4, 5, the sum of the exponents always being $= x$. For the Sulphoids and Phosphoids this discontinuity is expressed in the first corresponding strictly to metalloids, while the latter ($x = 3$) have metallic properties. The factors multiplying c will in all cases make y_3 the arithmetical mean between y_2 and y_4,

$$2\,y_3 = y_2 + y_4 \qquad (12)$$

as readily may be seen from (11).

We obtain again for x, y calculated, y observed, and the "correction," the values tabulated below.

For the sake of abbreviation, the function of x multiplying c is denoted by X, so that

$$\left.\begin{aligned} &\text{for } x = 1, 2 && X = 2^x \\ &\text{"} \quad 3, 4, 5 && X = 2^2 + 6.\ 2^{x-2} \end{aligned}\right\} \quad (13)$$

For the phosphoids and sulphoids, we have $b = 3$, for the chloroids $b = 2.5$. Hence we find

$$\left.\begin{aligned} &\text{for } \Phi \text{ and } \theta, && \tfrac{1}{2} X = 1, 2, 5, 8, 14 \\ &\text{"} \quad X && \tfrac{1}{2} X = 1, 2, 4._5, 7, 12 \end{aligned}\right\} \quad (14)$$

7. *Genus*. PHOSPHOIDS. $b = 3$.

$$\Phi = 7.5\,X \tag{15}$$

$\frac{1}{2}X = 1, 2, 5, 8, 14$ (see 14).

Nitrogen	1	15	14	−1
Phosphorus	2	30	31	+1
Arsenic	3	75	75	0
Antimony	4	120	122	+2
Bismuth	5	210	210	0

8. *Genus*. SULPHOIDS. $b = 3$, $\frac{1}{2}X = 1, 2, 5, 8, 14$.

$$\theta = 8.X \tag{16}$$

Oxygen	1	16	16	0
Sulphur	2	32	32	0
Selenium	3	60	79.4	−0.6
Tellurium	4	128	128	0
——	5	224	——	——

9. *Genus*. CHLOROIDS. $b = 2.5$. $\frac{1}{2}X = 1, 2, 4\frac{1}{2}, 7, 12$.

$$X = 9.X \tag{17}$$

Fluorine	1	18	19	+1
Chlorine	2	36	35.5	−0.5
Bromine	3	81	80	−1
Iodine	4	126	127	+1
——	——	216	——	——

We shall not discuss the "correction" which is to be applied to the calculated values in order to give the observed values. We only shall observe that these corrections are very small except for the three species *Fe*, *Ir*, *Pt*, which belong to genera known to contain varieties.

We do not mean to have the observed values corrected, for what here appears as "corrections" may in fact represent the links which hold together the various portions of the resulting atom. A negative correction would thus indicate that some projecting point had been removed before combination was effected.

Nor do we assert that the atoms of the so-called elements have a composition expressed by the general formula (4) (and its modification (11) for the metalloids); *but their atomic weights do make such composition probable*, while at the same time *such constitution would be the simplest possible if the elements were composed of one primary matter* (*pantogen*).

At all events it is thought that the relations here pointed out are of a more general and more rational character than those published by *Dumas* * in 1857.

In conclusion we give a synopsis of the formula represented by our generic symbols:

Genus in general $y = c.2^x + k$ (4)

Kaloids $Ka = 5.2^x + 3\,(-1)^x$ (6)
Cuproids $K\upsilon = (5\tfrac{1}{2}).2^x + 20$ (7)
Cadmoids $K\delta = 6.2^x + 16$ (8)
Terroids $\Sigma\iota = (6\tfrac{1}{4}).2^x + x\,(+1)^x$ (9)
Titanoids $T\tau = (6\tfrac{1}{2}).2^x + x\,(-1)^x$ (10)

Phosphoids $\Phi = (7\tfrac{1}{2}).\,[2^2 + 3.2^{x-2}]$ (15)
Sulphoids $\theta = 8\,[2^2 + 3.2^{x-2}]$ (16)
Chloroids $X = 9\,[2^2 + (2\tfrac{1}{2}).2^{x-2}]$ (17)
Sum of exponents is x. For $x = 1, 2$ the parenthesis is 2^x

Calcoids $Xa = 48\,x - 104$ (18)

From this it will be seen that the volatility and fusibility of the metals decreases as the value of c increases. Their *atomicity* increases with increasing c. For the metalloids the reverse is the case, which fact probably is connected with the electrical contrast between these two orders of elements.

Graphical representation, taking x as abscissa and y as ordinate, will conduce very much to a better apprehension of the relations and the general formula here presented. When presenting this subject to the Association a diagram about $2\frac{1}{2}$

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* L' Institut, 1857, pp. 420-422; pp. 383-386.

metres long was used; it contained the logarithmic or exponential curves for the Kaloids, Cuproids, Titanoids, Sulphoids and the straight line of the Calcoids. The unit of x was 18^{cm}, of y was 1^{cm}, so that $Bi = 210$ was represented by an ordinate of 210^{cm}.———

III. STAS' DETERMINATIONS.

Very much is said about these very interesting determinations of the atomic weight; but we believe that the true importance of these great labors is hardly estimated yet. Most chemists seem to think that the chief importance of the painstaking work of *Stas* is to disprove and forever reject the so-called hypothesis of *Prout;* and with the destruction of this hypothesis they seem to think all the palpable harmonies of the atomic weights, and particularly all relating to "*pantogen*" is annihilated. We are inclined to think that just such careful determinations *will demonstrate* the correctness of the law of a common divisor (equal one-half the atomic weight of hydrogen?) for all elements, *and* prove some essential features of the *structure* of the element atoms.

In order to approach this subject let us grant all that *Stas* does claim for his figures; that is, they are exact to the first or even the second decimals. *Let us see, what these figures, if they are so accurate as claimed, really do prove!*

The values of *Stas* are actually obtained for oxygen equal to 16. Let us represent these values by S. The atomic weights in accordance with *Prout's Law* (referred to one-half hydrogen) we shall for the sake of convenience call the *normal* atomic weights, A. The deviation of observation from these normal values we denote by D,

$$D = S - A \text{ or } S = A + D.$$

The deviation per unit of weight will then be

$$d = \frac{D}{A}$$

The values A, S, D and d are given in the following table, *S* being taken from *Fresenius' Zeitschrift für Analytische Chemie*, 1868, p. 169.

	A.	*S.*	*D.*	*d.*
KALOIDS, Kα, mean		. . .	. . .	+ 0.00284
Lithion, *Li*,	7	7.022	+ 0.022	+ 0.00314
Sodium, *Na*,	23	23.043	+ 0.043	+ 0.00187
Potassium, *Ka*,	39	39.137	+ 0.137	+ 0.00351
PHOSPHOIDS, Φ				
Nitrogen, *N*,	14	14.044	+ 0.044	+ 0.00314
PANTOIDS, Υ				
Hydrogen, *H*,	1	1.002	+ 0.002	+ 0.00200
SULPHOIDS, Θ				
Oxygen, *O*,	16	16.000	± 0.000	——
CHLOROIDS, X, mean		. . .	. . .	— 0.0008
Chlorine, *Cl*,	35.5	35.475	— 0.025	— 0.0007
Bromine, *Br*,	80	79.952	— 0.048	— 0.00060
Iodine, *Io*,	127	126.850	— 0.150	— 0.00118
CUPROIDS, Kυ				
Silver, *Ag*,	108	107.930	— 0.070	— 0.00064

It is apparent that *d* is nearly constant for the same genus, and very nearly + 0.003 for the Kaloids, — 0.001 for the Chloroids. In other words the deviation — whatever be its cause — is nearly proportional to the absolute weight determined!

Another very peculiar fact is the *positive* sign of the deviations, *D* and *d*, for the elements which are electro-positive in regard to the standard (oxygen), while the deviations are *negative* for the elements which are electro-negative in regard to oxygen. Silver forms the only exception to this rule. At the same time its deviation *d* is only 0.0006, or much *less* than that of all other elements except bromine; and the electro-chemical difference between silver and oxygen is not considerable either.

We conclude, therefore, that *Stas'* determinations *S* of the atomic weights deviate from the normal atomic weights *A* by small quantities *D* which

First, in regard to sign agree with the electro-chemical sign of the element in regard to oxygen (silver excepted); and

Second, are nearly proportional to the atomic weight itself.

Granted the accuracy of the determinations of *Stas*, the conclusions just given follow. We accordingly have a case in chemistry like that which astronomy would have offered if the perfection of the instruments and methods of observation had progressed more rapidly than theory, after the propounding of Kepler's laws. Then deviations from the elliptical orbits would have been observed, and it would have been discovered that these deviations were closely related to the relative position of the planets. If an expert observer on account of these deviations should have rejected *Kepler's* laws as disproved, he would have been greatly in error, because, as we now know, the observed deviations are consequences of the same law of gravitation on which *Kepler's* laws depend.

Now, theoretrical chemistry is vastly behind practical (empirical) chemistry, in fact, so much behind this latter that the claims of mathematical chemistry are generally either ignored or derided. We shall, therefore, not venture to give our explanation of the deviations *d*; we probably only would deter from those much needed researches, which will demonstrate what we now must leave as merely probable.

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3. ON THE GRAHAMITE OF WEST VIRGINIA, AND THE NEW COLORADO RESINOID. By HENRY WURTZ, of New York.

It is now nearly five years since my attention was first called to this remarkable mineral. I at once recognized the scientific interest that attaches to it, and have always earnestly desired to carry out some systematic and thorough chemical investigations into its nature and relations; a desire so far frustrated to a certain extent. Pending, however, renewed efforts which I am making, to accomplish complete elementary analyses of the constituents of Grahamite, as discovered by me, I think it my duty to communicate, for the first time, the full results of my former investigations.

Previous to 1865, the existence was frequently reported, and alluded to, in the public prints, of an extraordinary mineral formation on a branch of Hughes River, Ritchie County, West Virginia. It was sometimes called "Ritchie Coal," "Ritchie Asphaltum," "Crystallized (!) Petroleum," etc., etc. GESNER and others claimed it as identical with albertite, which they called an asphaltum (GESNER, *On Coal Oils*, *Petroleum*, *etc.*, p. 27).

The eminent geologist, Professor LESLEY, was the first to introduce its existence to the general knowledge of the scientific world, which he did in a communication to the American Academy in Philadelphia (in 1864, I believe) ; not having himself visited the locality, however. His opinion, founded chiefly on inspection of hand samples, was that the material was an "inspissated petroleum," or say, *a mineral pitch*. The results of my own examinations of some samples, made in January 1865, did not enable me to concur in this view, and I projected a visit to the locality, which I succeeded in carrying out in the ensuing summer. It was then accessible but by a very rough bridle path of fifteen miles, but now as I am told a branch railroad is completed from Cairo Station on the N. W. Virginia railroad.

The enclosing rocks are the ordinary blue sandstones and shales of the carboniferous, dipping generally about 15° or 17° N. W., in places nearly horizontal. The mineral occupies a vertical *dike-fissure*, it may be a shrinkage fissure, whose course is N. 76° to 80° E. A deep and narrow ravine cuts down deep into it, in the bottom of which some openings had well exposed the structure of the dike, which is obviously one of injection. My notes taken on the spot say in substance:

"The structure shows four distinct, though somewhat irregular, divisional planes, having a general parallelism with the walls. Next to the walls the structure of the mineral is coarsely granular, with an irregularly cuboidal jointed cleavage, very lustrous on the cleavage surfaces; that in immediate contact with the walls usually adhering thereto very tenaciously, as if *fused* fast to the granular sandstone.

"Next these two outside layers, which are very irregular and from two to three inches or more in thickness, is found, on each side of the vein, a layer averaging from fifteen to sixteen inches in thickness, which is composed of a variety highly columnar in structure and very lustrous in fracture, the columns being long, and, at this place, at right angles to the walls. It is this variety that was given to Professor LESLEY; as would appear from his description. Finally, in the centre of the vein, varying in thickness, but averaging about eighteen inches, is a mass differing greatly in aspect from the rest, being more compact and massive, much less lustrous in fracture, and with the columnar structure much less developed, in places not at all. The fracture and lustre of this portion of the vein are clearly *resinoid* in character.

"It is very remarkable that this curious dike-structure has heretofore escaped detection. Professor LESLEY, whose information, however, was derived at second hand, says that the mineral has 'not the slightest appearance of layers, but the aspect of complete uniformity and homogeneity.'

"The general aspect of the mass, as well as all the results of a minute examination of the accompanying phenomena, lead irresistibly to the conclusion that we have here a fissure which has been filled by an exudation, in a pasty condition, of a resinoid substance derived from, or formed by some metamorphosis of, unknown fossil matter contained in deep-seated strata intersected by the fissure or dike. It is not necessary to suppose a degree of fluidity greater than that of semi-fused pitch, or inspissated tar. Such a soft doughy mass, though flowing but slowly, would *in time* be forced by a very moderate pressure into every portion and into every crevice of the fissure. The peculiar structure described is such as would result from the fissuring of a fused or semi-fused viscous mass by the refrigeration produced by contact with the cold, and it may be wet, walls of the fissure; the outside granular layers being due to rapid cooling, and the columnar fracturing at right angles (or nearly so) to the walls (as, for example, in the case of a dike of columnar basalt) to a more gradual reduction of temperature, connected, without doubt, with the well known tendency of such materials as are susceptible of the vitreous or viscous fusion, to assume in time a concretionary or nodular structure. This tendency is strongly apparent in the brilliant variety, having produced multitudes of those curious markings on fissured surfaces which were mistaken in the case of the albertite for *fossil impressions*. The transverse columnar structure is called by LESLEY 'pencil cleavage.'

"Towards the extremities of the outcrop, where the sheet of mineral is thinner, this penicillate structure extends throughout the mass.

"The idea that this material was ever in the condition of fluid petroleum, is visionary and groundless, there being the strongest reason why it could never have been more fluid than a very thick semi-fluid pitch; of which reasons one of the most obvious is the entire absence of any penetration of the material into the surrounding porous sandstones. Also, no such substance as this, or anything approximating to it chemically, was ever known to be formed, or to have been formed, by the oxidation and inspissation of petroleum; and the formation from liquid petroleum, in such a fissure, to the depth of hundreds of feet, by any process of oxidation from the surface, of a mass so uniform as this, is an idea which I believe will receive but meagre acceptation among those chemists whose minds are free from the trammels of pet hypotheses.

"I will add, that I have yet to learn of the existence of *any* products (now forming) of oxidation or 'inspissation' (whatever that may be) of West Virginia petroleum.

"In sinking a small shaft here, twenty-eight feet deep, Mr. J. CARVILLE STOVIN, the engineer in charge at the time, found a detached fragment three and a half feet long of the north wall of the dike, imbedded in the mineral twenty-four inches distant from said wall, and twenty-nine inches vertically below the *hiatus* in the wall, marking its point of detachment; while exact measurements, both of itself and of the cavity left (on removing the mineral which occupied its original space) showed that it had become entirely inverted in position during its descent. The pitch-like semi-fluidity, which I have contended for, is here strongly illustrated, by the small depth of descent of this mass of quartzose sandstone, through a material whose density could not have been half of its own; while its distance from the wall and inverted position suggest that at the time of its detachment the dough-like mass was still rising, or in some sort of motion at least, in the dike-fissure.

"I myself observed similar *horses* of the wall rock, of small size, similarly imbedded in the mineral, at several points."

The density of a mass of the mineral was found to be 1.145. The horizontal extent of visible outcrop actually measured by me was five hundred and thirty fathoms, thinned out at east end to thirty inches, and at west end to eight inches; but as these points were at least seventy to eighty fathoms vertically higher than the bottom of the ravine, the width (averaging about fifty inches) at the latter depth points to a rapid widening of the fissure in descent. Allowing a uniform width of forty inches at the level of the bottom of the ravine, with the longitudinal extent measured, and with the above density; each fathom in depth at this level would contain two thousand tons. The depth to which it may extend is of course wholly unknown; but if the view I have provisionally adopted of the way in which this dike has originated be correct, it follows that it must widen in depth. This view I would present as follows:

By the action of heat upon strata of rock, containing fossil matter, and the pasty fusion of this fossil substance, and the partial gasefaction of itself and its contained water, with the uncontrollable expansion resulting therefrom, there has been opened a fissure through which the doughy mass, puffed up by bubbles of steam and other gases, escaped to the surface, or at least near enough to the surface to relieve the tension, and allow the steam and gases to escape gradually through the porous sandstone.

This hypothesis of mine seems the only one which reconciles an important difficulty besetting the other hypothesis (namely, that which creates a fissure originally filled with liquid petroleum, that has undergone "inspissation" from surface agencies); that is, the interference of water, which must necessarily have filled a preëxistent fissure, and opposed an obstacle to the subsequent infiltration of another fluid, at least if the latter were impelled by gravity alone. The supposition that the fissure itself was formed simultaneously with, and by, a fluid mass, containing within itself its own elastic expansive force, escapes this difficulty. I may also point out that it is not necessary to suppose that the *heat* which produced this expansive force was the central heat of the earth; for it is more probable that both the steam or gases, and the heat which expanded them, arose from a spontaneous decomposition (of the nature of fermentation) in the bed of fossil matter from which the grahamite exuded.

The view will occur that these original beds of fossil matter are beds of bituminous coal, as such coals without doubt underlie the locality. The only present support for such an idea, so far as I know, is the extraordinary statement of LESLEY, made on the oral authority of Professor HALL (see LESLEY'S Manual of Coal and its Topography, p. 165), of a "leader of coal" proceeding from a coal bed downwards into a limestone quarry, and there spreading out into a layer.

Chemical and Mineralogical Characters. This mineral is, in its actual identity or individuality, not only new, but cannot even be *classed* with certainty as yet, with any other mineral substance heretofore known and investigated by chemists. It is in its behavior with solvents especially, as well as with some other chemical agents, that those peculiarities are found, which establish it as a substance *sui generis.*

To the action of acids, alkalies and oxidating agents generally, it is quite indifferent. Concentrated boiling nitric and muriatic acids, and even *aqua regia*, have no action whatever upon it; nor has boiling sulphuric acid, if somewhat diluted. Oil of vitriol, however, even in the cold, forms a brown solution. The most concentrated caustic alkaline solutions are totally without action upon it.

Alcohol does not dissolve a trace of it. Naphtha, benzole and ether dissolve part of it; oil of turpentine gradually swells it up into tar-like magma, and then dissolves most of it; but its true solvents are *chloroform* and *sulphuret of carbon*, each of which apparently dissolves nearly the whole mass of the mineral with great rapidity, leaving nothing except the mineral matter (ash, = by analysis, about two per cent.), and some small proportion of coaly matter.

When heated in the open air it endures a temperature far above that of the fusing point of asphalts (which is usually below, and never much above, the boiling point of water) without change; but when heated above 400° F. it begins to decrepitate, smoke and soften, behaving very much like a highly caking coal.

The vapor given off under these circumstances I have found to be chiefly water. There is little or no smell, such as all asphalts give out when heated, and I may remark that no odor is given out when this mineral is broken, rubbed or scraped, or even from a mass of it lying in hot sunshine. The argument deducible herefrom, that it never could have been produced by the atmospheric oxidation of any other substance, and more particularly of petroleum, will be appreciated by chemists, at least. If the heat is now raised still higher, empyreumatic vapors appear, and indications of pasty fusion in the central and lower portions of the mass, though not upon the upper surface; the fact being that under ordinary atmospheric pressure the material is incapable of fusion without decomposition; but that under a very slightly increased pressure, even such as is developed by its own pasty cohesion at the caking temperature, a pitchy semi-fusion takes place. While in this condition the resinoid (or viscous) character of the material may be made strongly apparent, for by a little dexterous manipulation these central semi-fused portions of the mass may be drawn out into long, delicate threads, like semi-fused glass, sugar, or sealing wax. To my surprise I have found that by exceedingly careful manipulation with albertite, I could thread it out in the same way, though with far greater difficulty than with grahamite.

From the above it is clear that the West Virginia mineral can neither be identified, nor even classed, with coal, asphaltum, or albertite; and I have hence thought it both admissible and just to perpetuate in connection with it the name of the gentlemen who have been so energetic in promoting a public knowledge of this new material; by conferring upon it the new name *grahamite.*

The above statements were in substance comprehended in a pamphlet printed and privately circulated in the fall of 1865.*

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* An unsatisfactory account (to me) of this pamphlet was given in the *American Journal of Science*, xlii, p. 420; and DANA, in the latest edition of his Mineralogy, has adopted my name grahamite, although he still appears to take the view, which

It remains for me to present as concisely as possible, some of the results of my subsequent laboratory work upon grahamite, which, as before intimated, I am now preparing to extend farther.

The most important development made up to this time, has been the decomposition of grahamite (at least ninety-five per cent. of it) into two distinct resinoid substances, to which I have given, for reasons that will appear, the names *Viscosine* and *Irisine*. These are separated from each other by the action of solvents, viscosine being readily soluble in ether and petroleum-naphtha. The crude irisine remaining after the action of one of these solvents may then be extracted pure by one of its solvents, among which are *chloroform*, *bisulphide of carbon*, *oil of turpentine* and *benzole*. The dull compact core of the grahamite-dike contains a much smaller proportion of viscosine than the lustrous penicillate portions nearer the walls.

Ultimate organic analyses of grahamite, as a whole, have been made; but for several reasons, especially because of my observations of its mixed nature, I attach no importance to them, and shall not quote them. Analyses of pure viscosine and pure irisine, however, would be of high interest, and will in due time be made.

Properties of Viscosine. The liquid solutions formed by the action of a solvent of viscosine on the crude mineral possess a powerful olive-green fluorescence, exactly like that of many crude petroleums. The most lustrous samples of grahamite yield as much as twenty per cent. Dense solutions are as viscous as a thick syrup of glucose or a strong liquid glue.

Solid Viscosine. This is a substance of a very peculiar combination of physical and chemical characters. Though acquiring, by semi-fusion, a ductility and viscosity comparable to that of shellac and some others of the true resins, it is wholly sep-

I trusted I had overthrown, regarding the nature of the material, that it is "supposed to be like the albertite, an inspissated and oxygenated petroleum." DANA'S Mineralogy, p. 753).

Since the date of the publication of the above pamphlet, a paper was presented to the American Philosophical Society (see its *Proceedings* for July 1868, p. 457), by Prof. S. F. PECKHAM, in which, without knowledge of the above, views are taken singularly approximate to those I have expressed regarding the mode of origin of minerals of this class. From recent correspondence with Prof. PECKHAM, I learn that he will soon publish a paper, in which he himself points out this coincidence.—H .W.

arated from this class of substances by its chemical properties. Thus the most concentrated alkalies, even as fused hydrates, are wholly without action on it. Sodium remains indefinitely bright in a solution of viscosine in a liquid hydrocarbon, benzole for example; whence it appears to be a *hydrocarbon*, and, I believe, the first example of a hydrocarbon possessing a resinoid viscosity. Probably its most peculiar conjunction of properties is that of its passage, within very narrow limits of temperature or permeation by a solvent, to a solid form in which it is excessively brittle and fragile. On solidification from fusion its surface is extremely brilliant. When heated, viscosine melts readily to a thin liquid and finally distils partially unchanged. In a current of superheated steam it may be distilled over without change, except a darkening in color. The crude oil obtained by distilling grahamite contains much of it, especially when superheated steam is used. Freshly obtained, by evaporation of its etherial solution, it has a distinct balsamic odor, which after some time departs. In the mass it is brown; in powder buff-color; in thin layers nearly colorless.

I believe that this viscous hydrocarbon occurs in crude petroleums, and I have obtained a product from gas-tar approaching closely to it.

Irisine is inodorous; infusible without decomposition (except, probably, under heavy pressure); black in the mass, and pure dark brown in powder. When permeated with a small quantity of a solvent it has no viscosity, but is rather gelatinous and elastic, or slightly India-rubber-like in consistence, and shrinks enormously, and cracks accordingly, in drying.

It forms in solution in turpentine, chloroform, benzole, etc., very fine lustrous varnishes, which have the extraordinary property, when somewhat thinned, of always drying on polished surfaces to a *brilliant iridescence*, the colors having a sort of metallic depth and body only to be compared with those produced by heat on polished steel, while much brighter than the latter. This property has led me to confer upon this characteristic, and main constituent of grahamite, the special name *irisine*. There is much more in it than the mere phenomenon of thin films. I should suggest an extraordinary *low* refractive index for irisine, were this not difficult to reconcile with the fact I have observed that the presence of the *minutest quantity* of most other substances (viscosine excepted) in the solution impairs or wholly destroys the colors. It seems to me rather to be intimately connected with the peculiar *pure deep brown color* of irisine (combined, it may be, with a low index of refraction), and I am strongly desirous of assistance in the matter from some gentleman experienced in optical researches. Of such I should first of all ask whether the formation, in such a thin brown transparent film, of innumerable excessively minute *fissures*, seen against a specular background, could lead to the phenomena described? I refer of course to the property of irisine, above pointed out, of shrinkage, in desiccation from the colloid condition. This hypothesis would accord with the observation of the destruction of the color by small quantities of fatty and other substances, acting by alteration of the peculiar condition of *consistence* of irisine. Experiments to test this could doubtless be devised.

Another characteristic of irisine is that it is instantaneously altered and precipitated (from its solution, as an *insoluble modification*, by mere contact with a drop of sulphuric acid, and some other agents; becoming thereby *insoluble in all menstrua* yet tried. It may thus be prepared in a state of purity for analysis; and, moreover, as *animal charcoal* is one of the agents which have this power of modifying and precipitating irisine, while it has no action (except a decolorizing one) upon solutions of viscosine, we have also here a means of obtaining the latter perfectly free from irisine for the same purpose.

To the above strongly marked peculiarities of irisine, may be added its as yet almost unique conjunction of the properties of high solubility (when in the soluble modification) in so many solvents, with high infusibility. The conjecture is offered that bituminous coals contain the insoluble modification of irisine, or of substances of its class as yet unknown. In this connection I would recall that petroleums, and even distilled coal-oils contain substances precipitated by acids, but not yet investigated.

As to the *composition* of irisine, we have as yet no analysis. Experiments with sodium, which in time precipitates it completely from its solutions, would seem to indicate an oxygenated body; but as minute quantities of alkalies, as well as acids, convert it into its insoluble form, this is inconclusive. In organic combustions, great difficulty will be found, as its coke swells up and is excessively hard of combustion. I propose introducing it, however, into the combustion tube as a chloroform solution, in a sealed bulb, which may then be broken and the solution absorbed by the oxide of copper, the chloroform being of course removed before the combustion as vapor.

The Insoluble Residue of Grahamite. This, which is very small in quantity, as left by exhaustion with chloroform, was kindly examined for me with the microscope by Dr. JOHN TORREY. He reported that there was no trace of organic structure and it appeared to be mainly quartz sand.

Comparisons with other Substances. From all such, grahamite readily separates itself. Most so-called *asphalts* (a term I should wish to confine to products of subærial alteration of petroleums) differ from it greatly in their relations to solvents. Ether, for example, as stated by BOUSSINGAULT, DUMAS, and others, usually dissolves most of these. Still I believe that I have detected both of my new substances, viscosine and irisine, in some asphalts that I have examined.

Also, the benzole solution of albertite, comprising usually about twenty per cent. of the mineral, I find to contain viscosine, irisine, and another substance unknown as yet; eighty per cent., however, of the albertite is insoluble under ordinary circumstances, and may, possibly, though not probably, be *insoluble* irisine, or a homologue thereof. I propose farther investigation into this matter, and especially analyses of the proximate constituents of the albertite as obtained by the agencies of solvents, the only analyses, it seems to me, likely to be of much value.

BOUSSIGAULT'S *Caxitambite* comes no nearer; nor STERRY HUNT'S bituminous veins; nor "*Zopissa*" (which latter I found to be a greasy variety of asphalt).

The Colorado Dike. Four or five years since we began to hear of a curious formation in Colorado, believed to be albertite, which it very remarkably resembles in aspect. I was fortunate enough to obtain through the kindness of Dr. NEWBERRY, from the collection of the Columbia College School of Mines, a sufficient sample of an authentic specimen of the Colorado mineral to enable me to determine the surprising fact, now announced by me for the first time, that this is also *grahamite*, chemically almost identical with that of the West Virginia dike.

Its fracture is brilliant, but not so much so as albertite, and it is not penicillate like the glossy variety of grahamite. It contains scarcely any mineral impurity, dissolving wholly, without appreciable sediment, in chloroform, benzole, and oil of turpentine. Ether extracts about the same proportion as from glossy grahamite, with the same green fluorescence, and leaves, on evaporation, viscosine, identical in every way with that of grahamite. The residue from ether dissolves wholly in benzole, and gives all the reactions of irisine but is lighter in color, and the iridescences obtained are not so strong. Sulphuric acid wholly precipitates this Colorado irisine.

It may of course be anticipated that this highly characteristic species grahamite will be discovered elsewhere, two localities being already known, separated by the width of half the continent.

4. INVESTIGATIONS OF FLAME TEMPERATURES; IN THEIR RELATIONS TO COMPOSITION AND LUMINOSITY. By BENJAMIN SILLIMAN and HENRY WURTZ.

FIRST MEMOIR.—CALORIFIC POWERS OR EFFECTS OF GASES.

THESE subjects lie, in our belief, at the very basis of the true theory of the phenomena of luminiferous gases, and have practical bearings that can scarcely be overrated.

In fact, our studies of the subject have led us in the direction of the general conclusion that, all other conditions being equal, the *temperature*, in a given flame, is the main factor of luminosity. This, however, may as yet be regarded merely as a hypothesis; in consequence of the imperfection of our present means of actual experimental demonstration of the temperatures of flames. It is a hypothesis, nevertheless, which is in general accordance with known facts. By the spectroscope, for example, which can recognize only luminous rays, we find that the higher the temperature the greater the number of these luminous rays. The recent results of FRANKLAND upon the development of luminosity by increased pressure, in flames which are non-luminous under atmospheric pressure, are in accordance with this view; increase of temperature necessarily following increase of pressure.

Very vague views have been rife, even among chemists, with regard to the temperatures of luminiferous flames. Some have been satisfied with believing crude hypotheses; such as that the heat-power of a flame is always proportional to the *density* of the gas or vapor undergoing combustion; or that it is proportional to the *amount of oxygen consumed* by a given volume of the gas; and so on. This latter hypothesis has been one of very common acceptation. A view which is even now entertained by some skilful chemists (than which, however, nothing, as will be shown below, could be more fallacious) is, that those individual gaseous compounds which impart the highest luminosity under ordinary conditions, are also the most productive of heat.

The admirable researches of the great gas-chemist, BUNSEN, of Heidelberg, placed in our possession some years ago the means of computing, at least with approximate accuracy, the heat of flames of gases of known compositions. Few, however, have properly and successfully applied BUNSEN's methods in practice. We consider it quite time that these methods should be introduced to the knowledge of Gas-Engineers, in forms available to them.

BUNSEN's formulæ for these computations are based upon the actual experimental determinations of the *total* amounts of heat developed by the combustion of different pure combustible gases with pure oxygen, made by FAVRE and SILBERMANN; and upon REGNAULT's determinations of the specific heats of gaseous products of combustion.

It is not to be maintained that FAVRE and SILBERMANN's numbers are strictly correct, but they are doubtless approximate, and at least proportionally correct among themselves.

At any rate, they are the best data we have. Those employed here are included in the following table. They are usually given in the text-books for equal *weights* of the gases, but we have reduced them to the standard of equal *volumes* also, as more suitable to our present purpose. This reduction is made simply by multiplying the equivalents for weights, by the densities as given in the third column.

TABLE I.

	TOTAL CALORIFIC EQUIVALENTS.		DENSITIES ON SCALE OF HYDROGEN = I.
	Of Equal Weights.	Of Equal Volumes.	
Hydrogen, ...	34,462° C.	34,462° C.	1.
Carbonic Oxide, ...	2,403° "	33,642° "	14.
Marsh Gas, ...	13.063° "	104,504° "	8.
Olefiant Gas, ...	11,858° "	166,012° "	14.

The meaning of this table is simply that equal weights of water would be heated by the several gases to temperatures proportional to the numbers in the first column, when equal *weights* of the gases are burned; and proportional to those in the second column, when equal *volumes* are burned.

A cursory glance at the figures in the second column of this table might seem to justify the notion hitherto entertained by many, of the comparatively low calorific powers of hydrogen and carbonic oxide, and it was doubtless as a consequence of such a comparison as this that statements have been put forth, and widely accepted among American Gas-Engineers, to the effect that the weights of water heated from the freezing to the boiling point by one cubic foot of the four main components of illuminating gas, respectively, are as follows:

Hydrogen, ...	2.22	lbs, water
Carbonic Oxide, ...	2.16	" "
Marsh Gas, ...	6.17	" "
Olefiant Gas, ...	10.74	" "

The figures here being obviously about in the same ratio as those in the second column of Table I. Several most grave errors, however, are here involved. To get at the true relative calorific effects of the above gases, when burned in the open air, in heating water below its boiling point, deductions must be made, not only for the *specific heats* of the products of combustion of the gas, but also, more important still, for the specific heat of the *nitrogen of the air* required to burn the gas. In fact, when we consider that for each volume of oxygen required to burn a given volume of gas, about *four volumes* of nitrogen must be heated up to the temperature of the flame, it becomes easy to conceive, what is actually the fact, that within certain limits the waste of heat due to this cause alone counterbalances altogether the advantage that would be supposed to result from the crowding of combustible matter into so condensed a form as in the illuminating hydrocarbons. An inevitable result of our investigations of this matter, is that the heating powers of the flames of pure hydrogen and pure olefiant gas, even when used to the greatest advantage, to heat water below its boiling point, are almost or quite identical.

In this discussion we have occasion to use the numbers representing the specific heats of but *three* gases, the three, namely, which remain after complete combustion, *steam*, *carbonic acid* and *nitrogen;* as we must assume that in the hottest and most luminous zone or shell of the flame, there is no oxygen in excess to be heated. These three numbers are, according to REGNAULT's latest determinations, for equal weights of

Steam	0.4805
Carbonic acid	0.2163
Nitrogen	0.2438
(*Liquid water* being	1.0000)

That is, the amount of heat which would raise one pound of water and steam to the same degree are in the ratio of 0.4805 for the pound of steam and 1. for the pound of water.

CALCULATION OF THE CALORIFIC EFFECT OF HYDROGEN BURNING IN AIR.

Let us take, first, the simplest case possible, that of hydrogen with exactly the right admixture of pure oxygen to burn it, which, by Table I, develops a total heat of 34462° *C.;* that is, would heat a certain weight of *liquid* water to this temperature. In order to find the actual amount of heat contained in the products of combustion, we must first take into account the fact that one pound of hydrogen burns to *nine pounds* of steam, and then obtain the ratio between the above number, 34,462, and the amount of heat necessary to heat nine times the weight of steam, that is nine times the specific heat of steam. Calling the total residual heat in the produced steam x, we have the simple proportion:

$$9 \times (\text{Sp. heat of Steam} = 0.4805) : 34462 :: (\text{Sp. heat of Water} = 1) : x;$$

$$\text{or, } x = \frac{34462^\circ}{4.3245} = 7969^\circ\ C.^* = 14376^\circ\ F.;$$

a number which, we may add, represents the *maximum* of heat capable of being imparted *to liquid water* by the flame of Hare's oxyhydrogen blow-pipe.

Still, we have by no means here the actual temperature of the free or open flame of Hare's blow-pipe; which is greatly *lower* than this figure; as we have not yet taken into account the "latent heat," or heat of vaporization, of the nine pounds of steam formed. The Centigrade temperature necessary to convert one pound of water into steam being 537°; to get the *actual temperature* of the oxyhydrogen flame, we must modify the above equation, so that

$$x = \frac{34462^\circ - (9 \times 537^\circ)}{4.3245} = 6851^\circ\ C. = 12364^\circ\ F.$$

which is the temperature actually possible in the flame of the compound blow-pipe, *were the combustion instantaneous and complete*.

When hydrogen gas burns *in air*, however, as has been before stated, another deduction of enormous amount must be made from the above figures, due to the heat required to expand the nitrogen. This is obtained simply by adding to the divisor, as above, the weight of the nitrogen of the air employed, multiplied by its specific heat. The weight of the

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[*] Bunsen, in his Gasometry (English edition of 1857, p. 242), gives this number as 8061° *C.*, the difference being due to the use by him of a different number for the specific heat of steam, namely, 0.475, apparently an earlier determination of Regnault. Bunsen makes here the singular oversight of regarding this figure as the temperature, when "the gases can freely expand, as is the case in an open flame," overlooking the correction necessary in this case for the *latent heat of steam of combustion*, as is explained in the text above.

nitrogen in air = 3.318 times the oxygen; so that the latter of the above equations becomes

$$x = \frac{34462^\circ - (9 \times 537^\circ)}{4.3245 + (8 \times 3.318 \times 0.2438)} = 2744.5^\circ\ C. = 4972^\circ\ F.$$

[We wish to point out that we have here a full explanation of the extraordinary rate of degradation of illuminating gas by admixture of air, which we have discussed elsewhere. The nitrogen of such air is not merely a diluent, or even a mere deductive quantity; its specific heat is an actual *divisory* function in diminishing the flame temperature.]

This, then, is the actual temperature which the flame of hydrogen gas burning in the atmosphere might attain to, supposing complete and instantaneous combustion. If it is desired to obtain instead, the total calorific effectiveness, as in heating water below its boiling point—in which case the latent heat of the steam of combustion becomes also available—the above expression is changed by simply omitting the subtrahend in the numerator:

$$x = \frac{34462^\circ}{4.3245 + 6.4714} = 3192^\circ\ C. = 5778^\circ\ F.$$

CALCULATION OF THE CALORIFIC EFFECT OF CARBONIC OXIDE BURNING IN AIR.

As the product of combustion is here solely carbonic acid, no latent heat of steam enters, and the calorific effectiveness is the same, under all circumstances, in air. In the numerator we substitute of course the calorific equivalent of one volume of carbonic oxide from Table I; and in the denominator, for the specific heat of nine pounds of water, that of twenty-two pounds of carbonic acid, being the weight of the latter formed by the combustion and combination of fourteen pounds (weight of a volume of carbonic oxide on the hydrogen scale by third column of Table I.) of carbonic oxide, with eight pounds of oxygen. The number for the specific heat of nitrogen is the same as before, and the equation is now

$$x = \frac{33642^\circ}{(22 \times 02163) + 6.47 = 11.23} = 2996^\circ\ C. = 5425^\circ\ F.$$

MARSH GAS AND OLEFIANT GAS.

In these two cases, we have as products of combustion both carbonic acid and water; and, therefore, when the calorific effects are sought for, we have not only the latent heat of steam entering as a subtrahend into the numerator; but also into the denominator, as divisors, all three of the specific heats of steam, carbonic acid and nitrogen.

Then, as eight pounds of marsh gas consume thirty-two pounds of oxygen, and produce twenty-two pounds of carbonic acid, and eighteen pounds of steam; and as fourteen pounds of olefiant gas consume forty-eight pounds of oxygen, producing forty-four pounds of carbonic acid, and eighteen pounds of steam, the equations for the calorific powers of their flames in air become—

For marsh gas:

$$x = \frac{104504^\circ - (18. \times 537^\circ)}{(18. \times .4805) + (22. \times .2163) + (32. \times 3.318 \times .2438)} = 2414^\circ \text{ C} = 4386^\circ \text{ F}.$$

And for olefiant gas:

$$x = \frac{166012^\circ - (18. \times 537^\circ)}{(18. \times .4805) + (44. \times .2163) + (48. \times 3.318 \times .2438)} = 2743 \text{ C.} = 4970^\circ \text{ F}.$$

The following Table gives all the results of our calculations by the above methods.

TABLE II.

For Equal Volumes of the Gases Burning in Air.		Calorific Effects in Heating Liquid Water.		Calorific Effects above 100° C.	
		Centigrade Degrees.	Fahrenheit Degrees.	Centigrade Degrees.	Fahrenheit Degrees.
Hydrogen	(Sp. Heat HO = .4805)	3192°	5778°	2744°	4971°
	(Sp. Heat HO = .4750)	3204°	5799°	2755°	4991°
	(Mean, ...	3198°	5788°	2749°	4980°
Carbonic Oxide, ...		2996°	5425°	2996°	5425°
Marsh Gas,	(Sp. Heat HO = .4805)	2660°	4820°	2414°	4386°
Olefiant Gas,	" " .4805)	2916°	5481°	2743°	4970°

COMPUTATIONS OF CALORIFIC EFFECTS OF MIXED GASES.

The above Table renders the calculation of the calorific effects of any given gaseous mixture, whose centesimal composition is known, a matter of extreme simplicity. It is only necessary to obtain the sum of the multiples of the percentage of each component gas into its calorific capacity, as given in this Table, and divide by 100.

To serve as examples of these modes of computation, we here cite, in tabular forms, the results of some analyses of a number of gaseous mixtures made by us during the past winter (1868-69). [These analytical results, it may be remarked, possess points of novelty and importance, both scientific and practical, which will bring them up again hereafter, in other connections. They are here placed on record.]

Table III, gives the results of two analyses of gaseous mixtures obtained by passing steam *superheated to incandescence* upwards through a mass of *anthracite coal* heated to a high degree in a clay retort of a novel construction, according to what is now known as the *Gwynne-Harris*, or *American Hydrocarbon-Gas System.* In this table the results are calculated without carbonic acid and sulphuretted hydrogen, which, with traces of nitrogen, and sometimes of oxygen, are found in the unpurified anthracite gas.

TABLE III.

ANALYSES OF ANTHRACITE HYDROCARBON GAS:

BY SILLIMAN AND WURTZ.

	1.	2.	Mean.
Hydrogen, ...	60.43	59.32	59.87
Carbonic Oxide, ...	35.44	37.14	36.29
Marsh Gas, ...	4.13	3.54	3.84
	100.00	100.00	100.00

In Table IV, column (1) gives the results of an analysis of the street gas served out at this period by the *New Haven Gas-Light Co.*, made from Westmoreland coal enriched with about six per cent. of albertite. Column (2) exhibits the mean of four analyses of the completed Hydrocarbon Gas, made by us at Fair Haven during the same time by combining gas from the same Westmoreland coal (with ten per cent. of albertite) with half its volume of the anthracite gas.

Columns (3) and (4) are obtained from (1) and (2), by centesimal reduction, after deduction of the illuminant ingredients, being what we propose to designate as the non-illuminating *substrata* of illuminating gases.

TABLE IV.

ANALYSES OF ILLUMINATING GASES:

BY SILLIMAN AND WURTZ.

	(1.) New Haven City Gas.	(2.) Fair Haven Hydrocarbon Gas.	(3.) *Substratum* of New Haven Gas.	(4.) *Substratum* of Fair Haven Gas.
Hydrogen. . .	43.58	46.77	46.79	50.27
Carbonic Oxide,	2.14	9.56	2.31	10.27
Marsh Gas, . .	47.42	36.71	50.90	39.46
Illuminants, . .	6.86	6.96		
	100.00	100.00	100.00	100.00

Table V. gives the results of the computations, from our *formulæ*, of the calorific powers of these five gaseous mixtures, for communicating temperatures both above and below that of aqueous ebullition. We should remark that we have here been obliged to regard the volumes of *illuminant hydrocarbons* as representing olefiant gas solely; both because we have no certain data as to their real nature, and particularly because, if we actually knew, or should assume, the nature of the hydrocarbon vapors present, still we have no experimental calorific equivalents, as we have for olefiant gas, from which to start, in such a computation. We have reason to believe that the errors thus introduced are not important in amount.

The last two columns of Table V. have been calculated to furnish a direct comparison, for each of these gases, of its calorific power compared with that of the New Haven street gas, the latter taken as = 100.

TABLE V.

CALORIFIC EFFECTIVENESS OF GASEOUS MIXTURES; COMPUTED FROM THE FORMULÆ AND ANALYSES OF

SILLIMAN AND WURTZ.

	Weights of Water Equally Heated *Below* 100° C. by Equal Volumes.	Weights of Water Equally Heated *Above* 100° C. by Equal Volumes.	First Column reduced to New Haven Gas = 100.	Second Column reduced to New Haven Gas = 100.
Anthracite Gas, . .	3100	2833	104.2	109.2
New Haven Gas; *Substratum*,	2917	2561	98.1	98.6
Fair Haven Gas; *Substratum*,	2962	2640	99.6	102.0
New Haven Gas; with Illuminants assumed = Olefiant,	2974	2593	100.0	100.0
Fair Haven Gas; with Illuminants assumed = Olefiant,	2959	2647	99.5	102.1

Conclusions.—Some of the practical conclusions to which we are of necessity compelled, by the results of the above investigations, are so novel and remarkable, that we feel diffident regarding them. It is, however, always safe to follow the leading of Truth, however astray she may lead us from our preconceived notions.

It is apparent from Table II:

1. That of all known gases, the highest calorific effects, under ordinary atmospheric conditions, are obtainable from *carbonic oxide;* whose calorific value, above 100° *C.*, is about 3000° *C.*

2. That in absolute calorific value, below 100° *C.*, in the atmospheric medium, hydrogen surpasses its volume of any other gas; giving a temperature of about 3,200° *C.*

3. That for all modes of application—that is, for producing both high and low temperatures—the total maximum calorific effectiveness of carbonic oxide is a *constant quantity.**

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*Metallurgists, especially, will appreciate the suggestive import of the truths presented under the first and third heads; here enunciated, as we think, for the first time. It is to be noted that all the above effects belong to the *maximum* kind, and, of course, reach their development only under the most favorable conditions in each case respectively.

4. Compound condensed submultiple volumes of hydrogen, like that in marsh gas, have much *less* total calorific value in air than their volume of free hydrogen.

5. Condensed compound submultiple volumes of gaseous carbon, like that in olefiant gas, have no greater total calorific value, in air, below 100° *C.*, than their own volume of carbon gas in the form of carbonic oxide; while above 100° *C.*, their value is even considerably less.

The above investigations of calorific powers has been found by us a necessary preliminary to a more important and far more difficult experimental investigation of the subject of *Flame Temperatures*, which we have in progress, and upon the condition of which we hope to report at an early day. As it is fully recognized now (from the results of BUNSEN, BERTHELOT, DEVILLE and DEBRAY, and others) that in no body of burning gases, at any one time or place, does the *entirety* of the combustible constituents enter at once into the combustion; it is clear that the actual maximum temperatures, or calorific *intensities* of the flames of the above gases can in no case be so high as the figures established as above, by us, for their total calorific *powers*. Conditions enter here which render this problem one of the most complex and difficult that has yet been attacked by chemists.

5. ON SOME NEW PROPERTIES OF PHOSPHORIC ACID. By E. N. HORSFORD of Cambridge, Mass.

IT has long been known that phosphoric acid exists in three well marked modifications, distinguished as

Ordinary Phosphoric Acid,
Pyrophosphoric Acid, and
Metaphosphoric Acid.

The first combines with three atoms of base, the second with two atoms, and the third with but one. To Dr. Clarke of Aberdeen we owe the discovery of pyrophosphoric acid, and to Prof. Graham, of the Royal Mint, the discovery of metaphosphoric acid and the clearer definition of the characteristics by which the three acids are distinguished from each other. To Fleitmann, Henneberg and Maddrel are we indebted for a large addition to our knowledge of phosphoric acid, and especially of metaphosphoric acid. These chemists have presented us a series of metaphosphoric acids, which in their salts may be represented

$MeO. \quad Po_5$
$2\,MeO. \quad 2\,Po_5$
$3\,MeO. \quad 3\,Po_5$
$4\,MeO. \quad 4\,Po_5$
$6\,MeO. \quad 6\,Po_5$

and an acid of the constitution $6\,MeO. \quad 5\,Po_5$.

Dr. Clark long ago pointed out that ordinary phosphoric acid in solution concentrated till its temperature rose to 215° C was converted for the most part into pyrophosphoric acid. The same acid may be produced by ignition of tribasic phosphate of soda, and the metaphosphate by ignition of microcosmic salt — tribasic phosphate of soda, ammonia and water.

In these latter cases of conversion by heat, the characteristic acid was determined by the measure of fixed base present.

To these laws I have to add two more:

First, That whatever the relation of fixed base to acid is between one and three of base to one of acid, on ignition the acid potentiality subsides precisely to the horizon of the fixed base present.

Second, That within certain limits, greater, however, than these, that is, containing less than one of base to one of acid, this metamorphosis may take place when the base is lime by simple drying at ordinary temperatures; thus, for example, one of base to one of tribasic phosphoric acid, allowed spontaneously to dry by evaporation, will become the uniting equivalent of the base present — that is, the salt will become inert.

These two laws I discovered several years since, and desire to place them on record, as a duty to myself, although I am not prepared to present the full evidence which justifies the announcement. I may state, however, as a general illustration, that I have prepared an acid phosphate in crystalline form, in which the acid exceeded the ratio of one of tribasic acid to one of base, and have observed that whereas it had at the time of its preparation an acid strength which I will indicate by 100. A few days later its acid strength has fallen to 90; later still to 80; later still to 70; later still to 50; a year later to 0.

This acid, however, in contact with water, after a long time resumed its full energy, and in contact with a solution of soda resumed it with much greater rapidity.

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6. Phosphoric Acid, Iron and Potassium, Constituents of Chlorophyl. By E. N. Horsford of Cambridge, Mass.

At the meeting of the Association at Chicago, I announced the discovery of phosphoric acid as a constituent of the etherial solution of butter.

As the butter is derived from the food which the cows receive, the suggestion that it might be found in the ethereal solution of grasses and clover was natural. These were treated with ether, the solution, after two or three days, poured off and spontaneously evaporated to dryness. The residue was ground intimately with several times its volume of magnesia, previously demonstrated to be free from phosphoric acid; the mixture burned to whiteness and tested with nitric acid and molybdate of ammonia. This gave at once the characteristic yellow precipitate of phospho-molybdate of ammonia, thus proving the presence of phosphoric acid in the chlorophyl. The phosphoric acid was also determined as phosphate of ammonia and magnesia.

The chlorophyl was also treated directly with nitric acid, and where the ether had evaporated, and the wax-like body separated, to float on the surface of the liquid. Molybdate of ammonia gave from the solution the yellow precipitate, indicating the presence of phosphoric acid.

The readiest method for recognizing the phosphoric acid is to agitate the ethereal solution of chlorophyl with one-fourth its volume of concentrated muriatic acid, which resolves the green into two layers, one the blue below, the other the yellow above, as observed by Payen; and then separate the blue by dialysis into water containing a trace of ammonia. This liquid on the addition of nitric acid and boiling for a moment, gives, with molybdate of ammonia, the characteristic reaction for phosphoric acid. With sulphate of magnesia and ammonia, it gives the characteristic precipitate of ammonia-phosphate of magnesia.

From the same solution sulpho-cyanide of potassium gave the characteristic reaction for iron; and fero-cyanide of potassium gave with proper dilution at first only a green shade, becoming after exposure to the air for some time, Prussian blue, thus confirming the discovery of Verdeil of the presence of iron in chlorophyl. The flame of the chlorophyl residue gave with the spectroscope the red and blue lines of potassium. This observation, conducted with great care with the aid of Prof. Winlock and Prof. Watson, was so many times repeated as to leave no room for doubt on the point.

The examination for phosphoric acid was continued in the chlorophyl of the leaves of Indian corn, of the potato, of melons, squashes, sunflowers, the pear, cherry, apple, the Virginia creeper, the westeria and bignonia, the ash, elm, maple, oak, sumach, many varieties of shrubbery and flowering plants, the arbor vitæ, numerous fresh and salt water plants and indeed of most of the varieties of green vegetation that were accessible. Phosphoric acid was found in all. The ethereal extract of the larvæ feeding on the elm, which was for the most part chlorophyl, contained phosphoric acid.

It was noticed that the chlorophyl extract, when spontaneously dried down gave in each case some shade distinguished on account of its brightness, or dullness, or perishability, when kept for a short time.

In the ethereal extract of the colored petals of several cultitivated flowers, I found no phosphoric acid. It was wanting in the blue blossom of cichory. In the red flower of the bignonia it was found, but there seemed to be a certain quantity, small, but actual, of chlorophyl present. It was found only in traces in the extract of the purely red portion of the leaves of the coleus and zinnæ. In the extract of the red leaves of ripening Indian corn it was less and less, or wholly wanting, and the same was true of the yellow autumn leaves of the oak, maple, sumach and numerous other colored leaves which were examined.

While the green potato leaves yielded phosphoric acid in the ethereal extract, the white sprouts of potatoes grown in the dark did not contain it.

A great variety of fungi (mushrooms, edible or otherwise), of white, red and yellow coloration beneath, for the most part yielded to ether an extract containing waxy or fatty bodies, in which phosphoric acid was found.

The ethereal extract of English breakfast tea gave phosphoric acid, as did that of the wax of the bayberry, while that of bees' wax did not. It was not found in the ethereal extracts of white or brown muscovado or cane sugar, or cod liver oil. It cannot be doubted that phosphoric acid, iron and potassium are constituents of chlorophyl.

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7. ON THE RELATION BETWEEN THE INTENSITY OF LIGHT PRODUCED FROM THE COMBUSTION OF ILLUMINATING GAS AND THE VOLUME OF GAS CONSUMED. By BENJAMIN SILLIMAN of New Haven, Conn.

IN photometric observations made to determine the illuminating power or intensity of street gas, it is the practice of observers to compute their observations upon the assumed standard of five cubic feet of gas consumed for one hour, and in the constantly occurring case, of a variation from this standard, whether in the volume of the gas consumed or in the weight of spermaceti burned, the observed data are computed by the "rule of three," up or down, to the stated terms. The standard spermaceti candle is assumed to consume 120 grains of sperm in one hour, a rate which is rarely found exactly in actual experience.

For example, a given gas, too rich to burn in a standard Argand burner at the rate of five cubic feet per hour without smoking, is consumed at the rate of 3½ cubic feet to the hour, with an observed effect of 20 candles power. This result, previously corrected by the same rule for the sperm consumed, is then brought to the standard of five cubic feet by the ratio $3.5 : 20 = 5 : 28.57$.

The candle power of the gas is therefore stated as 28.57 candles, and this result has been universally accepted as a true expression of the intensity of the gas in question, or the relative value of the two consumptions.

In common with other observers I have long suspected that this mode of computation was seriously in error, as an expression of the true intensity of illuminating flames, and that there were other conditions besides the volume of gas or weight of sperm consumed which must influence, and greatly modify the results. As most of these conditions are considered somewhat at length in a paper on *Flame Temperatures*, prepared chiefly from researches conducted by Prof. Wurtz and myself, and presented at the Salem Meeting of the Association, they need not be discussed in this connection.

The results of many trials, made with the purpose of determining the value of these photometric ratios, indicate clearly, that the true ratio of increase in intensity in illuminating flames is, within certain limits, expressed by the following theorem, viz.:

The intensity of gas flames, i. e. *illuminating power*, *increases* (within the ordinary limits of consumption) *as the square of the volume of the gas consumed.*

As the first experimental demonstration of this theorem was made by Mr. William Farmer, the photometric observer at the Manhattan Gas Co.'s works in New York, I propose to speak of it as "Farmer's theorem." I am also indebted to Mr. Farmer and to Mr. Sabbaton, the well known and courteous Engineer of the Manhattan Gas Light Company, for the free use of their experimental data, and the permission to employ them in illustration of Farmer's theorem.

The fundamental importance of this new mode of computation will at once appear, if assuming it, for the sake of illustration to be true, we apply it to the case already given above which then becomes:

$$3.5_2 : 20 = 5_2 : 40.$$

Showing an increase of about forty per cent. over the old rule of correction. Let me see how far this theorem is sustained by the test of experiment.

Experiment 1*st*. Two similar gas flames, one at each end of the photometer bar, were made to give exactly the same intensity of illumination. This was accomplished of course by placing the Bunsen disc midway between the two burners, and regulating the combustion until the disc was perfectly neutral; the consumption being noted equal by two wet gas meters under the same pressure. The screen was then moved upon the bar to a point just four times as far from one flame as it was from the other, *i. e.*, the bar being 100 inches the screen stood at 80, *i. e.*, as 1 : 4. The light from the distant burner was then increased until the disc again showed an equality of illumination. On reading the rate of gas consumed by the two burners respectively, one gave 3.66 cubic feet and the other 7.32 cubic feet, or exactly double, or in other words the lights were as the square of the volumes of gas consumed, thus: $3.66_2 : 7.32_2 = 1 : 4$.

By the old rule the intensity would have been estimated directly as the volume of the gas consumed, thus:

$$3.06 : 7.32 = 1 : 2.$$

Experiment 2*d*. The following results were obtained with the use of a standard Argand burner. The readings of the index meter, the gas consumed in cubic feet, and the ratio of the lights produced, are given in three columns, viz.:

Index, .0550 = 3.30 feet. = 1 light.
" .0725 = 4.35 " = 2.1 "
" .0856 = 5.13 " = 3.2 "
" .0926 = 5.55 " = 4. "

In this series the lights increase in considerably higher ratio than is required by Farmer's theorem, which demands 6.60 cubic feet corresponding to a fourfold consumption, while the actual consumption was 1.05 cubic feet less than the quantity required by the theorem.

Experiment 3*d*. The following series was obtained by another Argand burner.

Index, .062 = 3.72 cub. feet, = 1 light.
" .0814 = 4.88 " = 2 "
" .1000 = 6.00 " = 3 "
" .1203 = 7.219 " = 4 "

In this series the ratio is more nearly in accordance with the demands of the theorem, the intensity being still a little in excess of the squares of consumption ($3.72 \times 2 = 7.44$ in place of 7.219).

The gas employed in these comparisons had a candle power of about 14 candles.

Experiment 4th. Results obtained by a comparison of fish-tail burners, ratio as 4 and 9 feet respectively.

A. Index, .0750 = 4.500 cub. feet. = 1 light.
B. " .1586 = 9.519 " = 4 "

In this comparison the ratio falls but little short of the demands of the theorem.

Experiment 5th. Comparison of fish-tail burners.

A. Index, .086 = 5.16 feet. = 1.85.
B. " .1677 = 10.06 " = 4.

In this trial the departure from the requirements of the theorem is considerably greater than in any of the preceding experiments. But it appears that from some cause the ratio of the squares does not hold with gas of the power used in these trials (14 candles), where the consumption rises above 9 or falls much below 3 cubic feet. This is undoubtedly connected with the well recognized fact, that there is for each gas a kind of burner and a volume of gas better calculated than any other, to develop its maximum intensity.

Experiment 6th. This series was designed by Mr. Farmer to test by a direct comparison the value of the new as contrasted with the old method of correction. Both trials were made upon the same gas, the second observation following immediately after the first and with the same candle, and therefore should give about the same candle power.

1st Trial. Consumption of sperm 32.7 grains.
" of gas 5.004 cubic feet.
Mean candle power (15 observations) 13.93 candles.

2d Trial. Consumption of sperm 32.2 grains.
" of gas 4.58 cubic feet.
Mean candle power of 15 observations 11.8 candles.

The above data calculated by Farmer's theorem.

5.004 cubic feet, and 32.7 grains give 15.15 candles.
4.58 " " " 32.2 " " 15.09 "

Difference, .06 "

Calculated by the old rule.

5.004 cubic feet and 32.7 grains give 15.16 candles.
4.58 " " " 32.2 " " 13.82 "
Difference, 1.34 "

It is obvious from the study of these results, that within the limits named the increase of intensity in gas flames, whether naked or Argand, is at a ratio certainly as great as the squares of the volumes of gas consumed; and hence it follows that all the photometric determinations, which have been obtained by computation from volumes greater or less than the assumed standard of five cubic feet per hour, in the simple ratio of the volumes consumed must be considered as quite worthless, provided the theorem of Farmer here announced is confirmed.

It is evident also that this theorem applies with equal force to the weight of sperm consumed by the standard candle as to the volumes of the gas burned in equal times.

With a view to test the theoreom of Farmer, I at once sought to apply it to the case of certain observations, I had made upon very rich gas obtained from cannel and other rich coals. The photometric power of these gases had been measured in the usual way heretofore practiced by observers, by burning a less quantity than five cubic feet in the standard Argand and then computing up to a standard of five cubic feet by direct ratio. The results of this comparison appear to go far to confirm Farmer's theorem.

Peytona Gas. This gas was made from a coal of West Virginia, known as Peytona Cannel Coal. It was much too rich to permit the flow of five cubic feet from the 15 hole Argand burner, with a perfect combustion. The gas was therefore reduced by mixture with a measured volume of street gas of known value and the illuminating power of the mixture having been carefully determined the value of the Peytona gas alone was readily calculated and fixed at 42.79 candles. The following trials exhibit the result obtained by burning smaller volumes of Peytona gas, and the values obtained by the two methods of calculation.

No. 1 Argand burner consuming 5 cubic feet per hour, mixed gas = 42.79 candles.
2 " " " 3.24 " " 18.95 "
3 " " " 3.48 " " 20.94 "

Here No. 1 represents very nearly the true illuminating power of the gas, and may be assumed as a fair criterion of the law under consideration.

By Farmer's Theorem.

No. 2 becomes $3.24^2 : 18.95 = 5^2 : 45.12$ candles.
3 " $3.48^2 : 20.94 = 5^2 : 43.22$ "

By direct ratio (old rule).

No. 2 becomes $3.24 : 18.95 = 5 : 29.24$ candles.
3 " $3.48 : 20.94 = 5 : 30.09$ "

By this it appears that by the old rule, assuming the true candle power of the gas to be 42.79 candles, the two observations, Nos. 2 and 3, are in error by about 30 per cent., while by Farmer's theorem the error is reduced to 3 per cent, the former being too small and the latter too large.

Albert Gas. The well known *Albertite* of New Brunswick, furnishes a gas of remarkable richness. Its true candle power can be measured only by diluting it largely with street gas of known value, and calculating it from the determined intensity of the mixture. In this way the gas from Albertite is shown to have an intensity equal to 70.38 candles. The following results were obtained by consuming different volumes in the burners named.

No. 1	Argand burner consuming	5 cubic feet	= 70.38 candles.
2	" " "	2.25 "	= 16.39 "
3	'Scotch tip' " "	3. "	= 25.25 "

By Farmer's Theorem.

No. 2 becomes $2.5^2 : 16.39 = 5^2 : 65.56$ candles.
3 " $3^2 : 25.25 = 5^2 : 70.14$ "

By simple ratio.

No. 2 becomes $2.5 : 16.39 = 5 : 32.78$ candles.
3 " $3 : 25.25 = 5 : 42.08$ "

The differences from the assumed standard of 70.38 candles are as follows:

By the old rule,	No. 2 falls short	37.6 candles or	115 pr. ct.
" Farmer's theorem	" " "	4.72 "	7.1 "
" the old rule,	No. 3 " "	28.30 "	67.25 "
" Farmer's theorem	" " "	0.24 "	0.34 "

It will be observed that No. 2, in this series, represents a consumption considerably below the minimum which in most cases experiment has shown to be the limit of the proposed theorem, namely: 3 cubic feet, while No. 3, which represents exactly this limit, brings the result within the range of experimental error — it being impossible to make two series of 15 photometric observations which will accord more closely than these.

Gas from the Ritchie Mineral. This gas was made from the mineral called *Grahamite* by Prof. Wurtz, and found in Western Virginia.

The gas made from this mineral was too rich to burn in the Argand burner with 5 cubic feet per hour.

1st. A mixture with Argand burner, and 5 cubic feet consumption.

80 per cent. street gas = 15.11 candles.
20 " " Ritchie " = 31.76 "
100 " " Mixture = 18.44 "

$$\frac{18.44 - 15.11 \times 80}{20} + 18.44 = 31.14 \text{ candles.}$$

2d. A mixture with Argand burner, and five cubic feet consumption.

78 per cent. poor gas = 13.72 candles
22 " " Ritchie = 31.01 "
100 Mixture = 17.53 "

$$\frac{17.532 - 13.720 \times 78}{22} + 17.532 = 31.05. \text{ candles.}$$

3d. Ritchie gas burnt with Scotch tip, and 5 cubic feet consumption, gave 30.01 candles.

4th. Ritchie gas, with Argand burner, and 4.056 cubic feet consumption, gave 19.24 candles, and for 5 cubic feet consumption, by squaring, 29.32 candles, and by old rule, 23.71.

No doubt the consumption here was too much for the Argand burner, as the illuminating power falls off somewhat from the preceding trials.

5th. Ritchie gas with Argand burner, and 3.876 cubic feet consumption, gave 18.66 candles; and for 5 cubic feet consumption by squaring 31.05 candles; and by the old rule, 24.07 candles.

6th. Ritchie gas with Argand burner, and 3.828 cubic feet consumption, gave 1879 candles; and for 5 cubic feet consumption by squaring 32.05 candles; and by old rule, 24.54 candles.

Mean of the 1st and 2nd tests by mixing = 31.40 candles.
" " " 4th, 5th and 6th tests by squaring = 30.80 " difference .60.
" " " 4th, 5th and 6th tests by old rule = 24.10 " " 7.30.

These results show plainly that the new theorem brings all the tests very near to the true illuminating power; certainly much nearer than the old rule.

Wollongong Gas. This gas was obtained from *wallongonite*, a new carbohydrogen described by me in the number of Silliman's Journal (for July, 1869), as coming from Australia. Its illuminating power was determined by mixing 10 per cent. of the gas with 90 per cent of street gas. But this mixture was still too rich to burn 5 cubic feet in the Argand standard without smoking, and even when burned at this rate in a fish-tail burner the flame was somewhat smoky and inclined to "tail off." I have, therefore, little doubt that its true candle power is more nearly 142 candles, than to 132, as stated in the article referred to. We quote, however, the observations made, as follows:

1 fish-tail burner consuming 5 cubic feet gave 132.94 candle power.
2 " " " 1.5 " " 12.89 " "

Computing the second observation we have:

By Farmer's theorem for No. 2, 143.22 candle power.
" direct ratio " " 42.96 " "

This is an extreme case in which the volume of gas consumed in the second observation is far too low, but it is clear that by the old rule the result coming from the consumption of so small a volume of gas is perfectly worthless, while by Farmer's theorem the difference of 10.28 candles is within 7.7 per cent., and if the true intensity of this remarkable gas is placed, as there is good reason to believe it should be, at 142 candles, the agreement in the two observations is absolute.

Every photometric observer can confirm the results here given by reference to his own records of former observations, or by direct experiment designed to test the accuracy of the theorem now announced.

In Sugg's *Gas Manipulation* (London, 1867), p. 64, will be found the following results from an experiment designed to illustrate the unfitness of the rule-of-three for calculating the illuminating power of gas, when using any other consumption than 5 cubic feet per hour.

ARGAND BURNER.

1.	5.	cubic feet	=	14.00	candles.	Differences.
2.	4.9	" "	=	13.78	"	— 0.22 of a candle.
3.	4.8	" "	=	13.74	"	— 0.26 " "
4.	4.7	" "	=	13.30	"	— 0.70 " "
5.	4.6	" "	=	13.04	"	— 0.96 " "
6.	4.5	" "	=	11.93	"	— 2.07 " "

The foregoing demonstrates two facts; first, that the Birmingham burner, even when burning the full quantity of 5 cubic feet per hour, does not show the true quality of the gas; and secondly, the inapplicability of the rule-of-three for estimating the light given in proportion to the quantity consumed, otherwise the whole of the results would have been 14.00 candles."

The quality of this gas, as exhibited by Dr. Letheby's burner, with 5 cubic feet consumption, and 120 grains of sperm per hour, was 15.50 candles.

The mean candle power of the five last tests is 13.158; diffence, 0.84 parts of a candle.

The mean candle power of the above tests, before they were corrected for five cubic feet consumption, will be as follows:

1.	5.	cubic feet	=	14.00	candles.
2.	4.9	" "	=	13.504	"
3.	4.8	" "	=	13.190	"
4.	4.7	" "	=	12.502	"
5.	4.6	" "	=	11.996	"
6.	4.5	" "	=	10.738	"

The above corrected for five feet consumption by Farmer's theorem.

1.	5.	cubic feet	=	14.00	candles.
2.	4.9	" "	=	14.060	"
3.	4.8	" "	=	14.312	"
4.	4.7	" "	=	14.148	"
5.	4.6	" "	=	14.191	"
6.	4.	" "	=	13.255	"

The mean candle power of the 5 last tests is 13.99; difference 0.01 parts of a candle.

The following will show the fractional power required to bring the five last tests to 14.00 candle.

2. $4.9^{1.83} : 13.504 :: 5^{1.83} : 14.00$ candles.
3. $4.8^{1.47} : 13.190 :: 5^{1.47} : 14.00$ "
4. $4.7^{1.85} : 12.502 :: 5^{1.85} : 14.00$ "
5. $4.6^{1.86} : 11.996 :: 5^{1.86} : 14.00$ "
6. $4.5^{2.52} : 10.737 :: 5^{2.52} : 14.00$ "

The above shows that the 3rd and 6th tests have not been good ones, or why should they differ so much from the one preceding them, the difference in consumption being only one-tenth of a foot?

The 2d, 3d, 4th and 5th tests fall a little below the square or 2d power, and the 6th test is considerably more.

The fractional powers of the 2nd, 4th and 5th are nearly the same.

I have endeavored to apply this theorem to some of the results recorded in the well known researches of Messrs. Audouin and Bérard,[*] but I find these results stated in a manner which renders it difficult to fix clearly the terms of comparison. I venture, however, to append a few comparisons drawn from two of the tabular records of experiments with butterfly or bats wing burners of the "fifth series" which, so far as they go, lend confirmation to the views here presented.

Consumption of the Burners under trial.	Consumption of the Bengel Argand standard burner without cone, 8 inch chimney.	Comparative intensities. The Bengel burner = 100.	Intensities by law of the squares of consumption.	Pressures.
Cubic feet.	Cubic feet.			
3.1079	3.6024	50	103	.23622
2.4015	3.5318	40	90.9	.19685
2.0131	3.6024	30	96.	.11811
Burners of same series—slit $\frac{1}{63}$ inch wide.				
3.9555	3.6730	80	92.6	.078474
3.1786	3.6730	60	80.7	.07480
2.6487	3.6730	50	96.7	.07480
2.3309	3.6730	40	97.5	.03937
1.5186	3.6730	20	115.6	.01968

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[*] *Ann. de Ch. Et Phys.*, vol. lxv, p. 428, 1862.

The comparison of their results by this theorem, which gives reasonably exact results for consumptions which are not greater than that of the standard Bengel burner employed by them, fails when the consumption becomes greater than that of the standard.

A comparison of the foregoing results will show that the coincidences with the requirements of the theorem of Farmer are, within the limits assigned, too numerous, and too closely accordant, to be considered as otherwise than pointing clearly to its general truth. A rigorous demonstration cannot be expected as there are too many variable functions of unknown value involved in the best methods at present known for photometric measurements to permit more than an approximate proof of its general accuracy. Every photometric observer must recognize its importance and the necessity in his observations of bringing the consumptions of gas and sperm to the agreed standard.

To the consumer of gas the evident inference from the data here presented is that where it is important to obtain a maximum of economical effect from the consumption of a given volume of illuminating gas, this result is best obtained by the use of burners of ample flow.

Where a moderate light of equal diffusion is required over a large space, as in public rooms, it may be expedient to use numerous small jets; but when the maximum intensity obtainable from a given volume of illuminating gas is desired, intensity burners of large consumption are plainly indicated.

8. ON THE COMPOSITION OF THE ACID OXALATES OF POTASSIUM, AMMONIUM AND SODIUM. By WILLIAM RIPLEY NICHOLS, of Boston, Mass.

BINOXALATE OF POTASSIUM.

THE composition of this salt was formerly held to be expressed by the formula* $KO, C_4 O_6 + 3\, HO$ $(\text{Ꞓ}_2 KH \Theta_4 + aq.)$

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* On the authority of Graham, Phil. Tr. 1837, 50.

and this formula is still given by Gmelin, Watts, and others, as that of the commonly occurring salt.

Rammelsberg,* on the other hand, describes the salt obtained by neutralizing a certain quantity of oxalic acid with carbonate of potassium, and adding an equal amount of oxalic acid, as corresponding to the formula $2\,(KO,\ C_4O_6) + 3\,aq.$ $[4\,(\bar{C}_2KH\Theta_4) + aq.]$

Marignac,† having afterwards partially analyzed this salt, concluded that the correct formula was C_4KHO_8 $(\bar{C}_2KH\Theta_4)$ and that the crystals contained no water of crystallization. He differed from Rammelsberg as to the system to which the crystals should be referred, and the latter afterwards ‡ acknowledges the correctness of Marignac's views as to the crystalline form and, without repeating the analysis of the salt, seems satisfied to accept the formula assigned by Marignac.

I have prepared this salt in the manner indicated by Rammelsberg, and find that its composition agrees with the formula originally given by him.

	Calculated.		Found.								
			I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean.
$2K_2\Theta$	188.44	35.53	—	—	—	35.55	35.05	—	—	—	35.30
$4\bar{C}_2\Theta_3$	288.00	54.29	55.35	55.67	55.76	—	—	—	—	—	55.76
$3\,aq.$	54.00	10.18	—	—	—	—	—	10.16	10.39	10.58	10.34
$4\,(\bar{C}_2KH\Theta_4) + aq.$	530.44	100.00									

In these analyses I determined the potassium as carbonate by igniting a portion of the finely powdered crystals in a covered platinum crucible, raising the heat very gradually in order to avoid loss by projection, to which, as Marignac hints, this salt is particularly liable. The oxalic acid was determined by titration with a solution of permanganate of potassium standardized against pure oxalic acid. The hydrogen was determined by igniting the salt in a combustion tube, in a stream of dry air, and collecting the water in a weighed chloride of calcium tube.

	Rammelsberg's			
	formula demands.	own figures were.		
$2KO$	35.53	36.41	35.22	35.36
$2C_4O_6$	54.29	55.31	54.32	54.00
$3\,aq.$	10.18	—	—	—
	100.00			

	Marignac's		
	formula demands.	own figures were.	
KO	36.78	36.35	(Mean of four.)
C_4O_6	56.19	55.86	
HO	7.03	—	
	100.00		

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* Pogg. Ann. XCIII, 24 (1854).

† Mém. de la Soc. d. Phys. et d'Hist. Nat. de Genève, T. XIV, part I. (1855).

‡ Supplement zu dem Handbuch der krystallographischen Chemie. Leipzic, 1857, s. 81.

Had Marignac determined the hydrogen in his salt, he would have found his formula to be inadmissible.

In regard to the acid oxalate described by Graham (loc. cit.),* it is extremely doubtful whether there be such a salt. Rammelsberg† doubts its existence, and I have myself been unable to procure it. I added to a hot solution of a known quantity of oxalic acid, half the carbonate of potassium necessary to neutralize it. The crystals which formed in the hot solution (A), those deposited from the solution at the ordinary temperature (B), as well as those deposited when the solution was artificially cooled to a considerably lower temperature (C), proved to be the quadroxalate $Є_2 K H \Theta_4,\ Є_2 H_2 \Theta_4,\ + 2\,aq.$

	Calculated.		Found.					
			A.			B.		C.
			I.	II.	III.	I.	II.	I.
$K_2\Theta$	94.22	18.54	—	—	18.41	18.53	—	—
$4\,Є_2\Theta_3$	288.00	56.67	56.23	56.52	—	—	56.86	56.83
$3\,H_2\Theta$	54.00	24.79	—	—	—	—	—	—
$4\,aq.$	72.00							
$2\,(Є_2 KH\Theta_4,\ Є_2 H_2\Theta_4,\ +2\,aq.)$	508.22	100.00						

In these estimations the potassium was determined as carbonate, by ignition, and the oxalic acid by titration, as in the preceding case.

I analyzed several samples of commercial "binoxalate of potash," but each sample proved to be quadroxalate.

BINOXALATE OF AMMONIUM.

This salt was prepared by neutralizing a certain quantity of oxalic acid with ammonia-water, and then adding an equal quantity of oxalic acid. Analysis showed the composition of the salt to be $2\,(Є_2\,(NH_4)\,H\Theta_4) + aq.$

	Calculated.		Found.				
			I.	II.	III.	IV.	Mean.
$(NH_4)_2\Theta$	52	22.41	—	—	21.54	—	21.54
$2\,Є_2\Theta_3$	144	62.08	61.35	61.57	—	—	61.46
$H_2\Theta$	18	7.75	—	—	—	—	—
$aq.$	18	7.76	—	—	—	7.50	7.50
$2\,(Є_2\,(NH_4)\,H\Theta_4) + aq.$	232	100.00					

	Calc.	Found.
* KO	32.24	32.34
C_4O_6	49.28	—
$3\,HO$	18.48	—
	100.00	

Graham deduced this formula from the amount of carbonate of potassium left on ignition (47.45 per cent.).

† Pogg. Ann. XCIII, 24 (supra cit.).

The formula usually given in text-books on chemistry (Gmelin, Watts, etc.), is $C_4(NH_4)HO_8 + 2\ aq.$ $\text{Ȼ}_2(NH_4)H\text{Ɵ}_4 + aq.$, that is, with one more molecule of water than I find to be the case. For this formula the calculated percentages would be

$(NH_4)_2\text{Ɵ}$	52	20.80
$2\text{Ȼ}_2\text{Ɵ}_3$	144	57.60
$H_2\text{Ɵ}$	18	7.20
$2\ aq.$	36	14.40
100.00	250	

Anderson* says that the binoxalate of ammonium may be obtained by mixing equivalent quantities of chloride of ammonium and oxalic acid (regarded as monobasic; $C_2O_3, HO + 2\ aq. = 63$), and gives as the formula $2\,C_2O_3, NH_4O, 2\,HO$ $[2\,(\text{Ȼ}_2(NH_4, H\text{Ɵ}_4) + aq.]$.

He determined the oxalic acid alone, and, from the data that he gives, it would appear that, instead of the binoxalate, he really obtained the quadroxalate mentioned below.

Percentage of $\text{Ȼ}_2\text{Ɵ}_3$		
in his salt.	in the acid salt above.	in the hyperacid salt below.
61.92	62.08	61.80.

I found that by adding a hot solution of 53.5 grm. (1 eq.) chloride of ammonium (NH_4Cl), to a hot solution of 63 grm. ($\frac{1}{2}$ eq.) of crystallized oxalic acid ($\text{Ȼ}_2H_2\text{Ɵ}_4 + 2\ aq.$), there were deposited on cooling crystals of the hyperacid salt of the formula $\text{Ȼ}_2(NH_4)H\text{Ɵ}_4, \text{Ȼ}_2H_2\text{Ɵ}_4, + 2\ aq.$

	Calculated.		Found.						
			I.	II.	III.	IV.	V.	VI.	Mean.
$(NH_4)_2\text{Ɵ}$	52	11.16	11.12	11.29	—	—	—	—	11.20
$4\text{Ȼ}_2\text{Ɵ}_3$	288	61.80	—	—	61.14	61.14	61.09	—	61.12
$3\,H_2\text{Ɵ}$	54	11.59	—	—	—	—	—	—	—
$4\ aq.$	72	15.45	—	—	—	—	—	15.81	15.81
$2(\text{Ȼ}_2(NH_4)H\text{Ɵ}_4, \text{Ȼ}_2H_2\text{Ɵ}_4, + 2\ aq.)$	466	100.00							

In these analyses the ammonium was determined as chloroplatinate of ammonium, the oxalic acid by titration, and the water of crystallization by drying at 100° $C.$, until the weight remained constant.

BINOXALATE OF SODIUM.

Anderson (loc. cit.) says that, by dissolving equivalent proportions of oxalic acid (equiv. = 63) and chloride of sodium (equiv. = 58.5), in hot water, crystals of this salt are obtained on cooling the solution. He gives the formula for the same $NaO,\ 2\,C_2O_3 + 4\,HO\ [2\,(\text{Є}_2NaH\Theta_4) + 3\,aq.]$

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* Qu. Jour. Ch. Soc. I. 231 (1849).

I found that crystals of the binoxalate were deposited from such a mixture, but that they answered to the commonly received formula $C_4NaHO_8 + 2\,aq.\ [\text{Є}_2NaH\Theta_4 + aq.]$

	Calculated.		Found.		
			I.	II.	Mean.
$Na_2\Theta$	62	23.85	—	—	—
$2\,\text{Є}_2\Theta_3$	144	55.38	55.19	55.24	55.22
$H_2\Theta$ $2\,aq.$	54	20.77	—	—	—
$2\,(\text{Є}_2NaH\Theta_4 + aq.)$	260	100.00			

9. On the Solubility in Water of the Oxalates of Sodium, Potassium and Ammonium, at the ordinary temperature of the Air. By William Ripley Nichols.

In determining the solubilities of the salts experimented upon, the method employed to obtain solutions, saturated at the observed temperatures, was as follows:—Considerable quantities of the salts operated upon, several times as much as would be likely to dissolve in the amount of water used, were put into glass-stoppered bottles, which were then half filled with distilled water, and placed in a pan of water so as to be immersed up to the necks. The operation was carried on in a room where the variation of temperature was slight, such variation being noted by means of a thermometer suspended in the pan of water.

The bottles were shaken conscientiously at frequent intervals for two or three days, and, finally, portions of the solutions were filtered through dry filters, into tared flasks, and weighed. As a rule the thermometer had indicated a constant temperature for several hours previous to the filtration.

The amount of oxalic acid in the weighed solution, was determined by titration with permanganate of potassium, standardized against pure oxalic acid and from this result the amount of salt dissolved was calculated.

In every case but one, the salts were prepared by myself, and in every case the character and purity of the salt in question was ascertained by titrating a weighed portion of the dry salt with the standard solution of permanganate of potassium.

OXALATE OF SODIUM.

$$\text{€}_2 Na_2 \Theta_4.$$

This salt was prepared by neutralizing a hot solution of oxalic acid with pure carbonate of sodium. The oxalic acid used in preparing this, as well as the other salts, left upon ignition 0.03 per cent. ash.

	Calculated.		Found. I.	II.	Mean.
$Na_2\Theta$	62	46.27	—	—	—
$\text{€}_2\Theta_3$	72	53.73	54.06	53.62	53.84
	134	100.00			

Solubility.—Temperature at time of filtration, . . 13° C.
Temperature had varied during solution from 11° to 13.5°.

100 parts of the solution saturated at 13° contain:

I.	II.	III.	Mean.	
3.063	3.066	3.047	3.059	parts of the crystallized salt.

Or, 100 parts of water at 13° dissolve 3.156 parts of the crystallized salt.

Or, 1 part of the crystallized salt is soluble in 31.6 parts of water at 13°.

This agrees with the determination of Souchay and Lensen* who say that one part of the salt dissolves in 31.1 parts of water at 15.5°.

Pohl† says that one part of salt dissolves in 26.7 parts of water at 21.8°.

BINOXALATE OF SODIUM.

$$\text{€}_2 Na H \Theta_4 + aq.$$

This salt was prepared by adding 58.5 grm. (1 eq.) of chloride of sodium in solution, to a hot solution of 63 grm. ($\frac{1}{2}$ eq.) of crystallized oxalic acid, and recrystallizing the product deposited from the solution when cold.

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* Ann. Ch. u. Ph. XCIX. 33 (1856).

† Wien. Acad. Ber. VI. 596 (1851).

	Calculated.		Found.		
			I.	II.	Mean.
$Na_2\Theta$	62	23.85	—	—	—
$2\,\text{€}_2\Theta_3$	144	55.38	55.08	55.35	55.22
$3\,H_2\Theta$	54	20.77	—	—	—
$2(\text{€}_2 Na H \Theta + aq.)$	260	100.00			

Solubility.—Temperature at time of filtration, . . 10°.
Temperature had varied between 5° and 10°.
100 parts of the solution saturated at 10° contain:

I.	II.	III.	Mean.	
1.40	1.39	1.55	1.45	parts of the crystallized salt.

Or, 100 parts of water at 10° dissolve 1.48 parts of the crystallized salt.

Or, one part of the crystallized salt dissolves in 67.57 parts of water at 10°.

Souchay and Lensen (loc. cit.) say that one part of the salt dissolves in 60.3 parts of water at 15.5°.

OXALATE OF POTASSIUM.

$$\text{€}_2 K_2 \Theta_4 + aq.$$

This salt was prepared by neutralizing a commercial sample of quadroxalate of potassium with carbonate of potassium and recrystallizing twice.

	Calculated.		Found.			
			I.	II.	III.	Mean.
$K_2\Theta$	94.22	51.14	—	—	—	—
$\text{€}_2\Theta_3$	72.00	39.08	38.99	39.63	38.53	39.05
$H_2\Theta$	18.00	9.78	—	—	—	—
$\text{€}_2 K_2 \Theta_4 + aq.$	184.22	100.00				

Solubility.—Temperature at time of filtration, . . 16°.
Temperature had varied between 12° and 16°.
(The temperature had remained at 16° for several hours.)
100 parts of the solution saturated at 16° contain:

I.	II.	Mean.	
24.73	24.89	24.81	parts of the crystallized salt.

Or, 100 parts of water at 16° dissolve 32.99 parts of the crystallized salt.

Or, one part of the crystallized salt is soluble in 3.03 parts of water at 16°.

BINOXALATE OF POTASSIUM.

$$4\,(Ȼ_2 KH\Theta_4) + aq.$$

This salt was prepared as stated in the preceding paper.

Solubility.—Temperature for three hours preceding filtration, 8°
Temperature had varied between 8° and 10.5°.

100 parts of the solution saturated at 8° contain:

I.	II.	III.	Mean.	
3.680	3.681	3.668	3.676	parts of the crystallized salt.

Or, 100 parts of water at 8° dissolve 3.816 parts of the crystallized salt.

Or, one part of the crystallized salt is soluble in 26.21 parts of water at 8°.

QUADROXALATE OF POTASSIUM.

$$Ȼ_2 KH\Theta_4,\ Ȼ_2 H_2\Theta_4 + 2\,aq.$$

This salt was prepared by recrystallizing a sample of commercial "binoxalate of potash".

	Calculated.		Found.				
			I.	II.	III.	IV.	Mean.
$K_2\Theta$	94.22	18.54	—	—	—	18.45	18.45
$4\,Ȼ_2\Theta_3$	288.00	56.67	55.80	55.63	55.77	—	55.75
$3\,H_2\Theta$	54.00	24.79	—	—	—	—	—
$4\,aq.$	72.00						
$2\,(Ȼ_2 KH\Theta_4, Ȼ_2 H_2\Theta_4, +2\,aq.)$	508.22	100.00					

Solubility.—Temperature at time of filtration, . . 13°.
Temperature had varied between 12° and 14.5°.

100 parts of the solution saturated at 13° contain:

I.	II.	Mean.	
1.774	1.784	1.779	parts of the crystallized salt.

Or, one part of the salt is soluble in 55.25 parts of water at 13°.

Or, 100 parts of water at 13° dissolve 1.81 parts of the crystallized salt.

Pohl (loc. cit.) says that 100 parts of water at 20.6° dissolve 4.957 parts of the salt dried at 100° (5.775 parts of the crystallized salt), which would go to show that the solubility must increase rapidly with the temperature.

OXALATE OF AMMONIUM.

$$\text{Є}_2(NH_4)_2\Theta_4 + aq.$$

This salt was prepared by neutralizing a hot solution of oxalic acid with ammonia-water.

	Calculated.		Found.			
			I.	II.	III.	Mean.
$(NH_4)_2\Theta$	52	36.62	—	—	—	—
$\text{Є}_2\Theta_3$	72	50.70	50.72	50.92	51.48	51.04
$aq.$	18	12.68	—	—	—	—
$\text{Є}_2(NH_4)_2\Theta_4 + aq.$	142	100.00				

Solubility.—Temperature at time of filtration, . . 15°.
Temperature had varied between 13.5° and 15°.

100 parts of the solution saturated at 15° contain:

I.	II.	Mean.	
4.028	4.076	4.052	parts of the crystallized salt.

Or, 100 parts of water at 15° dissolve 4.22 parts of the crystallized salt.

Or, 1 part of the crystallized salt dissolves in 23.69 parts of water at 15°.

I verified the statement of Heintz* that this salt is less soluble in a solution of chloride of ammonium than in pure water. I added chloride of ammonium to a concentrated solution of the salt, and there were deposited small crystals which gave by titration 50.93 per cent. $\text{Є}_2\Theta_3$, showing that they were actually the normal oxalate.

BINOXALATE OF AMMONIUM.

$$2[\text{Є}_2(NH_4)H\Theta_4] + aq.$$

This salt was prepared as stated in the previous paper.

Solubility.—Temperature at time of filtration, . . 11.5°.
Variation of temperature—slight.

100 parts of the solution saturated at 11.5° contain:

I.	II.	III.	Mean.	
5.89	5.91	5.88	5.896	parts of the crystallized salt.

Or, 100 parts of water at 11.5° dissolve 6.26 parts of the crystallized salt.

Or, 1 part of the crystallized salt is soluble in 15.97 parts of water at 11.5°.

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* Zeitsch. f. d. ges. Naturw. XX, 29.

In order to ascertain whether this salt dissolved unchanged, a portion of that remaining undissolved, was titrated with the standard permanganate, and the percentage of oxalic acid found agreed with that of the original salt.

QUADROXALATE OF AMMONIUM.

$$\text{€}_2(NH_4)H\Theta_4, \text{€}_2H_2\Theta_4 + 2\,aq.$$

This salt was prepared by adding to half an equivalent of oxalic acid ($\text{€}_2H_2\Theta_4 + 2\,aq.$) an equivalent of chloride of ammonium (NH_4Cl), as described in the preceding paper.

Solubility.—Temperature at time of filtration, 7.75°.
Temperature had varied but slightly.

100 parts of the solution saturated at 7.75° contain:

I.	II.	III.	Mean.	
2.45	2.46	2.46	2.46	parts of the crystallized salt.

Or, 100 parts of water at 7.75° dissolve 2.52 parts of the crystallized salt.

Or, one part of the crystallized salt is soluble in 39.68 parts of water at 7.75°.

OXALIC ACID.

$$\text{€}_2H_2\Theta_4 + 2\,aq.$$

A portion of pure crystallized oxalic acid was taken, and its solubility determined to be as follows:

Solubility.—Temperature at time of filtration, 14.5°.
Variation of temperature—slight.

100 parts of the solution saturated at 14.5° contain:

I.	II.	III.	Mean.	
8.668	8.777	8.754	8.733	parts of the crystallized salt.

Or, 100 parts of water at 14.5° dissolve 9.56 parts of the crystallized salt.

Or, one part of the crystallized salt is soluble in 10.46 parts of water at 14.5°.

THE FOREGOING RESULTS MAY BE TABULATED AS FOLLOWS:—

NAME OF SALT.		Temperature.	100 parts of the saturated solution contain parts salt.	100 parts water dissolve parts salt.	1 part salt soluble in parts water.
Oxalic Acid, ...	$Ꞓ_2H_2Ө_4$ + 2 aq.	14.5°	8.73	9.56	10.46
Oxalate of Sodium, ...	$Ꞓ_2Na_2Ө_4$	13°	3.06	3.16	31.60
Binoxalate of Sodium, . .	$Ꞓ_2NaHӨ_4$ + aq.	10°	1.45	1.48	67.57
Oxalate of Potassium, . .	$Ꞓ_2K_2Ө_4$ + aq.	16°	24.81	32.99	3.03
Binoxalate of Potassium, .	$4(Ꞓ_2KHӨ_4)$ + aq.	8°	3.68	3.82	26.21
Quadroxalate of Potassium,	$Ꞓ_2KHӨ_4, Ꞓ_2H_2Ө_4$ + 2 aq.	13°	1.78	1.81	55.25
Oxalate of Ammonium, . .	$Ꞓ_2(NH_4)_2Ө_4$ + aq.	15°	4.05	4.22	23.69
Binoxalate of Ammonium, .	$2(Ꞓ_2(NH_4)HӨ_4)$ + aq.	11.5°	5.89	6.26	15.97
Quadroxalate of Ammonium,	$Ꞓ_2(NH_4)HӨ_4, Ꞓ_2H_2Ө_4$ + 2 aq.	7.75°	2.46	2.52	39.68

B. NATURAL HISTORY.

GEOLOGY AND PALÆONTOLOGY.

1. On the Cretaceous Age of Silver-deposits in Chihuahua, Mexico, by James P. Kimball, of New York.

A tour made last autumn and winter, from the Texas coast to the Grand Sierras, or Cordilleras of Mexico, near the thirtieth parallel, afforded a few geological observations of such importance that I venture to lay them before the Association. It will not be necessary on this occasion to enter into minute description. But the few points I have now to offer will, I trust, serve partly to bridge the gap in the knowledge of the country between the Rio Grande on the east, and the Cordilleras; and to rectify a number of errors which mainly make up the meagre geological part of what otherwise is an interesting brief account of Chihuahua—that of Dr. Wislezenus of Col. Doniphan's Expedition in 1846–7, whose report, together with that of the Mexican Boundary Survey, contain the only references of any consequence to the geology of Chihuahua, to be found in any language—so seldom has any other part of the state than the High Sierras been visited by scientific travellers, while even that part, comparatively accessible from the Pacific Coast, is, along with the rest of the state, less known than any other portion of Mexico.

The Cretaceous formation which overspreads Central Texas, where it has been carefully studied by Professor Roemer and Dr. B. F. Shumard, is traced westward under pretty uniform conditions, beyond the Pecos, forming the table-land of the intervening belt, until, in the Limpia Mountains, its familiar features disappear and a new order of things supervenes. Up to this line the geology of Texas has been fixed. Within the great bend of the Rio Grande, the water-shed between the

Pecos and that river, presents geological features which have been described by travellers whose studies have not extended far into Chihuahua. While these features are anomalous in Texas, they prevail in Chihuahua, and are to be regarded, as I propose to show, as an extension of the same conditions which characterize the whole of the eastern slope of the Cordilleras in the north-eastern part of Mexico.

Topographically considered, the whole surface of Texas is a part of the slope of the Mexican Cordilleras. From the Gulf of Mexico to the Limpia Mountains, which are only a part of a long dividing range between the Pecos and the Rio Grande, extending from New Mexico, there is a constant acclivity toward the west, which, gradual, until the Alluvial, Diluvial, and Tertiary coast margin is passed, becomes very marked as soon as the Cretaceous rocky strata set in. From San Antonio, five hundred and seventy-nine feet above the sea, which is near the line between the Tertiary and Cretaceous formations, the Cretaceous surface rises to three thousand and ninety-eight feet, at Leon Springs (some two hundred and eighty miles farther west), and to near four thousand feet before the fossiliferous Cretaceous strata are covered by the rocks which form the Limpia Mountains. These mountains present a thickness from eight hundred to one thousand feet of a rock of peculiar character, which has been described in the Report of the Mexican Boundary Survey, as a porphyry, and as furnishing a "coarse granitic aggregate of which adularia forms a large part," both of which varieties, together with compact quartz, are referred to an *igneous* source: whence the inference is drawn that the Limpia Mountains, as well as what is mentioned as a continuation of the same range — the Sierra Rica, in Mexico — are an axis of elevation. From all these points I have to dissent.

First, as to the lithological character of the Limpia Mountains. Although clearly porphyritic in its structure, and containing (yet rarely) small segregations rather than crystals of orthoclase, it presents, to the eye at least, the novel condition of a non-feldspathic matrix, and therefore, in the restricted sense of the term, can hardly be called a porphyry. The matrix is a ferruginous compact quartz, through which are diffused, besides orthoclasic, minute quartz, crystallizations. Hence this rock is rather to be characterized as a porphyritic quartzite. These characters are uncommonly pronounced where the rock first sets in, namely, at Hackberry Ponds.

This is an extension of the same formation which overspreads a large part of Chihuahua — a fact ascertained by continuity and relative stratigraphical position, rather than by lithological uniformity. The rock is disposed in strata which are gently undulating. Its ferruginous character causes it to weather excessively — especially where its consistency is not very dense. In the eroded valley of the Limpia, bold cliffs of it are seen weathered into massive picturesque columns of a dark ochreous color. The ferruginous coloring matter is present in the interior as red oxyd. At Fort Davis a quarry in this rock furnishes a building-stone, called by the Mexicans *cantera.* Here its porphyritic characters have entirely disappeared, its quality being a loose alumino-silicious aggregate. It may be cut with a saw, and much resembles the building-stone or *cantera* in use in the city of Chihuahua, and quarried in metamorphic strata at the same horizon as this. The same rapid transitions in consistency, yet a constant uniformity of its peculiar type, are witnessed throughout the wide development of this rock which I will afterwards designate as *cantera* (a Spanish word, simply meaning, however, building-stone). Its metamorphic character is indicated by phenomena already mentioned; while the formation of the Limpia Mountains, by the mere accumulation of nearly level strata, is so distinct as to give no appearance of an axis of elevation. The relation of the metamorphic *cantera* to the underlying Cretaceous limestone, is revealed by a quarry below the level of the plain, which supplies the lime-kiln of the post.

From the head of the Limpia, near Fort Davis, to Presidio del Norte, on the Rio Grande, there is a gradual descent of over twelve hundred feet. The *cantera,* which in high bluffs skirts the valley-plains for some distance, comes down to the level of the road some sixty miles this side of the Rio Grande, and is succeeded by fossiliferous limestone, some thirty miles farther. The river terraces, five or six in number, begin ten to twelve miles from the river. Passing a corresponding set of terraces on the west side, the surface begins immediately to ascend in impure limestones and calcareous shales, dipping 15° to the north-west. The limestone, of a sandy character, contains numerous fossils, some in great abundance, among which are forms of Cretaceous fauna known in Texas, viz.: *Exogyra plicata*, *Scalaria Texana*, *Natica Texana*, *Lima Wacoensis*, together with species of *Ammonites Ostrea*, and *Inoceramus*, and fish teeth. The Sierra de las Cuestas, which form the bluffs of the Rio Grande valley proper, and the continuation of these mountains to the south—the Sierra Rica—are made up of this Cretaceous series. The latter mountains are the centre of a slight dislocation which imparts to the series north-west dips from 15° to 20°, as seen in the mountains themselves, where the succession is, (1) lower shales and fissile slates; (2) blue limestone with *inoceramus;* (3) upper fissile calcareous shales; (4) arenaceous cavernous limestone with *inoceramus;* (5) a coarse metamorphic rock made up of crystalline quartz and orthoclase. The Sierra Rica lode, bearing sulphurets of silver and of the base metals is encased in this fossiliferous series, its highest outcrop being on the crest of a prong from which the quartzose rock of the neighboring summits has been stripped by denudation.

The Conchos River valley seems to occupy an anticlinal axis of an elevation of the Cretaceous limestone series, the western part of which has been obliterated by river erosion, and only its eastern part preserved in the form of a gentle monoclinal, with a dip to the south-east. Such, at least, appears to be the structure of the Cuchillo Parado, the Chupaderos and Chorreras Mountains, as seen from the Chihuahua road, which keeps along their base, across the Jornada or great barren plain of Rosales. At its western end, where the bordering mountains draw together at the gap of the Gallina, between the mountains of that name on the east, and the Chupaderos on the west, a sudden increase of the south-east dip of the limestone, lets in the summit *cantera* with a sufficient thickness to form the mountains to the south and east of the Jornada; while westward the Chorreras range continues to raise the limestone in heights, from three hundred to five hundred feet, until obliterated at the bend of the Conchos, which cuts across it, and whose valley here spreads out some twenty-five miles, under the erosive influence of the close confluence with it of the Sacramento and Rosales branches. In this interval the limestone passes below the surface, and the metamorphic *cantera* sets in to form the elevations which, in north and south ranges from five to ten miles broad, separated by wide and longitudinally remarkably continuous valleys or valley plains, succeed each other all the way to the culminating line of the Cordilleras, and thus characterize their eastern flank in this latitude. An acclivity of the whole surface, toward the west, is very marked —all the way indeed from the Rio Grande, the road rising from two thousand seven hundred and seventy-nine feet above the sea at Presidio del Norte, to four thousand six hundred and forty at the city of Chihuahua, and six thousand two hundred and seventy-five feet at Cusihuiriachic, the culminating point (Cumbres de Jesus Maria) being only four hundred and fifty-seven feet higher than the Peak of Cusihuiriachic, or eight thousand three hundred and seventy-five feet above the sea.

This longitudinal succession of narrow ranges and wide champaign valleys, gives rise to a peculiar topography whose phenomena are mainly those of diluvial and alluvial erosion. The north-east dip of the *cantera*, though liable to local variations, is, on the whole, scarcely greater than the incline of the general surface. It is always seen under rapid disintegration, especially its more ferruginous portions. Its fine detritus overspreads all the valley-plains in such thick and ever growing accumulations, as often to fill up former water-courses. Those which do not contain running streams, all have a basin configuration: that is, a depressed portion toward the middle; while toward their borders the foot hills of the intervening mountains are seen in all stages of degradation. Thus the valleys are widening at the expense of the mountains; and their plain-like character is increasing under the determination of the finer detritus toward their former channels, now often dry except during the brief rainy season. These observations are true equally throughout the development of the metamorphic *cantera* in western Texas as throughout Chihuahua, north of the twenty-eighth parallel which I did not pass to the south. These phenomena, replete with interest, I can take occasion now only thus briefly to note. One other observation in a general way, however, I may add. It is that these and closely related phenomena, point to the elevation of the whole eastern Cretaceous slope of the Cordilleras, comprising Chihuahua and the greater part of Texas, since the outlines of the present topography were determined by water-courses, now either entirely obliterated, or else taking an inconsiderable part in the river system of this extensive area.

It will be understood that what I have distinguished as *cantera* forms, with the exception of what I have called the limestone range, along the western base of which flows the Conchos, as much of the surface of Chihuahua as comes under observation in traversing the state by way of Presidio del Norte and the city of Chihuahua, as far west as Cusihuiriachic — a point pretty well up toward the summit of the Cordilleras, — and as far north as El Paso by the road from the city of Chihuahua. This *cantera* overlies the Cretaceous fossiliferous limestone, and is, I regard, a metamorphic upper member of that formation.

I now come to the point the importance of which alone could warrant me in troubling you with local descriptions, namely: (1) that the seat of the principal known silver deposits of eastern and middle Chihuahua, is the Cretaceous fossiliferous limestone; and (2) that the seat of other great deposits is the overlying *cantera;* also, I am disposed to think, of Cretaceous age, a metamorphosed superior zone of that formation.

The Santa Eulalia range of mountains, one of the characteristic ranges already described, lies about half way between the Conchos and the city of Chihuahua. These mountains are mainly composed of quartziferous cantera, somewhat porphyritic; but in the heart of them rises a boss of the underlying limestone in which are found the old Spanish silver mines of Santa Eulalia. Coextensive with this elevation of the limestone, and confined to it, is the mining ground comprising an area of not more than five square miles. From 1705 to 1791, during a period of 86 years these mines, according to official records, yielded $100,000,000 on which the *quinto* or King's fifth was paid to the royal exchequer. To this product from a fifth to a third more is to be added for yield clandestinely obtained. The boss rises some eight hundred feet above the bordering plains and some five hundred feet above its immediate base. It is scored by water-courses, giving rise to deep cañons, in the bottoms of which and along whose bluffs the mines have been opened wherever access by bridle paths could be got, while the tops of the limestone hills have likewise afforded entrance. The silver deposits are of a very irregular description. The bulk of them is an invisible chlorid of silver minutely diffused through a decomposed and ferruginous matrix, sometimes associated with a low grade of argentiferous galena, and sometimes with salts of lead, and varying in richness from twenty-five dollars to one hundred and twenty-five dollars per ton. Occasionally rich pockets are found in which occur visible sulphurets of silver, and crystals of horn-silver. This argentiferous material is found with quartz, gypsum and calcspar, disposed between planes of stratification, or oblique joints in the beds; or in irregular decomposed courses in massive beds: sometimes thoroughly disseminated through a portion of a bed or a number of beds, and occasionally in drusy cavites. No particular choice seems to be given to any bed or any set of beds, but all alike have been, and are still, worked with much the same results. The whole series of beds is exceedingly cavernous. Natural caves, into which workings lead, were shown me capable of holding, it is said, the great cathedral of Chihuahua. This remarkable and unique character of the deposits has led both to vertical and horizontal workings. The same beds which are entered by caverns in the elevated portion, are reached by shafts in the bordering cañons, as the dips bear them from above water level. All the beds are more or less fossiliferous. *Inoceramus*, *Radiolites*, *Pecten*, and a well preserved coral, together with other Cretaceous forms, being found outside any of the mines, but generally on weathered surfaces from which it is difficult to remove them.

Besides the silver deposits in the Cretaceous limestone of Sierra Rica and Santa Eulalia, the intermediate limestone range at many points sustains a similar metalliferous character—argentiferous galena being well known in Mexico to occur in the Cuchillo Parado, in the Chupaderos and the Chorreras; while, in Texas, I saw in the possession of Major

General Merritt, stibnite and galena from the Chanate Mountains — probably from the same fossiliferous Cretaceous horizon — inasmuch as I have a *Pecten* of that period from the same locality.

Another slight isolated elevation of the limestone, on a prolongation of the axis of the forementioned range, occurs low toward the base of the Sierra de Magistral between the city of Chihuahua and Cusihuiriachic. This locality is also well known as an old mining ground. The excellent silver mines of Corralitas, according to the Mexican Boundary Survey, are likewise in blue limestone, and though its age has not been determined, I may venture to predict it will likewise prove to be Cretaceous. (Rep. Mex. Bound. Surv. II, p. 1, Vol. I, 12.)

Throughout its development, the *cantera* of the mountains, or the metamorphic Cretaceous, as I believe it to be, also sustains a highly metalliferous character. With the exception of the limestone range (including the localities already mentioned) it is the seat of all the silver deposits within the section of country visited by me as far west as Cusihuiriachic, and undoubtedly considerably farther, as evidences taken at second hand tend to show. Gold as well as silver occurs in this formation.

The extensive old Spanish silver mines of Cieneguilla richly affording horn-silver in brecciated fissures traversing the *cantera* are located some sixty-five miles south-west of the city of Chihuahua. Some fifteen miles still farther south-west are the remarkable mines of Cusihuiriachic. The mining village of that name has an altitude of six thousand two hundred and seventy-five feet. Above it rises the *bufa* of the same name one thousand six hundred and forty-three feet. The flanks, of this mountain, whose outlines have been determined by erosion, are traversed by noble fissures filled out with a complex vein-stuff of great richness in silver. A number of specimens, selected, but averaged according to grade, collected and assayed by myself, yielded from one hundred and forty dollars to thirteen hundred and fifty dollars per ton. These mines, under a practice both rude and desultory, have produced, in the course of two centuries, some $100,000,000. The quartziferous character of the *cantera* here predominates.

Here, as elsewhere, the more exposed portions exhibit the most strongly marked metamorphic aspect, as if its metamorphism had been effected by molecular and chemical changes of an alumino-silicious or felspathic, and perhaps somewhat calcareous and magnesian, aggregate, under the influence of the atmosphere and percolating waters. As tending to such a view, it will be necessary only to instance, besides its stratigraphical conditions and attitude, the apparent elimination of its more soluble ingredients as indicated both by the vesicular character of weathered surfaces, and by the remarkable fact that in all low places wherever the *cantera* is extensively developed, a rubble is found cemented by a carbonated base. This cementing material seems to have been derived from mineral percolations springing from the surperincumbent rocks. Such a concrete is found also under the detritus which, supplied by the *cantera* of the mountains, covers the valley-plains. Another observation bearing on this point, is the frequent occurrence of the soft earthy aggregate, or the typical *cantera* (building-stone) as a *portion* of the formation, particularly at the base of mountains, below or near natural drainage. Moreover, the *cantera*, both hard and soft, indicates in part a detrital origin by its inclosure of breccia and pebbles, thus bearing out the general impression it gives of altered felspathic sediments.

Professor Gabb has recently called attention to the occurrence of Texan Cretaceous fauna in Sonora, where they were found by the late Mr. Rémond, as going to show a "water communication between the great Cretaceous sea that covered so much of what is now the central portions of our continent, on the one side, and the Pacific on the other. The recognition of the Cretaceous near Arivechi in Sonora, according to Mr. Gabb, was only the second locality reported of its occurrence in the whole area of Mexico, the other being in the State of Puebla.

Although the metamorphic Cretaceous is, through the labors of the California Survey, well known in numerous localities in the coast ranges, as a seat of gold deposits and the Jurassic, east of the Cordilleras within the territory of the United States, of silver deposits, the instances which I have just given, of the unequivocal fossiliferous Cretaceous, as well as a probable metamorphic and later zone of the same formation, as sources of silver ores, are the first, I believe, yet brought to light in North America. The only similar occurrence of which I am aware is in Chili, where, according to Mr. Rémond, calcareous and fossiliferous Cretaceous strata, the same as at Santa Eulalia, carry irregular silver deposits.*

2. REMARKS ON THE AGE AND RELATIONS OF THE METAMORPHIC ROCKS OF NEW BRUNSWICK AND MAINE. By GEORGE F. MATTHEW and L. W. BAILEY, of the Geological Survey of Canada.

THE sediments to which the following remarks chiefly relate, are embraced in the most southerly of three spurs projecting to the north-east, from that extensive tract of altered and often highly crystalline rocks which occupy the greater part of New England; and lie between the unaltered Silurian of New York on the one hand, and the New Brunswick coal field on the other.

Dr. Gesner, who made a geological survey of New Brunswick between the years 1838 and 1842, recognized the existence of granitic ridges in two of these spurs, and spoke of the slates in the central part of the Province as Cambrian, while those which lie near the Bay of Fundy were described as Silurian. Subsequently the late Dr. James Robb, of King's College, Fredericton, in a geological map published about 1850, and in an explanatory chapter in Johnston's "Report on the Agricultural Capabilities of New Brunswick," retained in the main this arrangement. In both cases it would appear that the classification was based upon the highly altered character of the rocks, and the paucity or entire absence of organic remains.

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*See an article by the writer in the American Journal of Arts and Sciences, vol. xlviii, 1869, p. 378. Notes on the Geology of Western Texas and of Chihuahua Mexico.

Very little was added to our knowledge of these obscure and puzzling formations for a number of years. About the year 1858, one of the authors of this paper, Mr. George F. Matthew, began observations at the city of St. John, resulting in discoveries which enabled Dr. J. W. Dawson to pronounce some of the deposits in that vicinity to be of Upper Devonian age. At the beginning of the present decade, a Geological Survey of the State of Maine, under Prof. C. H. Hitchcock, was undertaken, through which a knowledge of the age of some of the metamorphic rocks adjoining New Brunswick was obtained.* In the following year the characters of the metamorphic belt eastward of St. John were observed during a reconnoissance made for the Government of New Brunswick by the authors of this paper, in connection with Prof. C. F. Hartt. We were enabled to show the existence of Laurentian, Huronian and Primordial strata in the tract examined, and of Upper Silurian in Charlotte County, as well as to indicate the wide distribution of Devonian sediments along the coast both east and west of the St. John River. A large area, however, of altered rocks between the latter and the border of Maine, still remained in great part unknown.

When the work of the Geological Survey of Canada was extended to this Province in 1868, the authors of this paper undertook the examination of the area to which reference has been made. The following remarks embrace the principal results obtained by us, together with a summary of the facts at present known with reference to the structure of this and the neighboring regions.

LAURENTIAN SERIES.

The assemblage of rocks referred to this system occupy an area surrounded by more recent formations, about forty miles long and eight broad, extending from Mace's Bay, an indentation of the Bay of Fundy, north-eastward into King's County. It is well exposed in the Narrows of the St. John River, a few miles northward of the city of the same name.

The succession in this series is much obscured by faults and overlaps, but exhibits a repetition of beds similar in mineralogical characters to that observable in the same series elsewhere. It presents a great body of gneiss, often granitoid in aspect, and includes one or more bands of crystalline limestone, constituting veritable limestone formations many hundred feet in thickness, interstratified, however, with beds of quartzite and diorite. The limestones are in some cases fine-grained, but in others very coarsely crystalline, and include workable beds of crystalline graphite. Some of the limestones are micaceous, and they are often mixed with a pale green translucent *serpentine*, closely resembling that found in the Laurentian limestones of other parts of the continent.

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* We shall have occasion to refer to the voluminous observations made in parts of the State farther west, by Prof. Hitchcock, in the sequel.

In the south-western part of Charlotte County there is another area and several small patches of granitic and syenitic gneiss,* with gneiss conglomerate, which, mainly on lithological grounds, we are disposed to refer to the same formation. Limestones, however, are much less abundant in these than in the Laurentian of St. John County.

LABRADOR SERIES.

Several hills of crystalline felspar rock, associated with hypersthene,† and in some cases with magnetic iron, are found lying between the Laurentian and the Cambrian in St. John County. Dr. Hunt, who has recently visited the locality, considers them to be identical with the anorthosite felspar rocks of the Labrador or Upper Laurentian series, and is disposed to refer them to that formation.

CAMBRIAN OR HURONIAN SERIES.

The rocks referred to this series are exposed in two bands extending north-eastward from near the city of St. John, each about thirty miles long and three or four wide. Their greatest observed thickness is about ten miles east of St. John, where it is apparently not less than seven thousand feet. Westward this thickness becomes, within a short distance, very greatly reduced, and where the beds cross the St. John River does not exceed fifty feet. Beyond this point, in the same direction, they have not been recognized.

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* The largest exposure of these syenites has hitherto been regarded as a part of the long granite ridge represented in maps heretofore made, as extending through the metamorphic area south of the coal-field. They are evidently much older than the slates around them, and are quite different from the Nerepis granites to which we shall have occasion to refer in the sequel. They are regarded by Dr. Hunt as true Laurentian rocks.

† The hypersthene of this rock is sometimes in cleavable crystals one or two inches across.

The beds of this series consist mainly of hard felspathic rocks, often approximating to a petrosilex. They are more or less quartzose and generally epidotic, and vary in color from pale greenish or reddish to gray and dark gray. With them are associated considerable masses of diorite. At the base are hard red quartzose conglomerates and red argillaceous sandstones, and at the summit softer red sediments of the same color. In the finer felspathic rocks the stratification is often obscure, but may generally be detected in the coarser beds, which, towards both the base and summit, become a conglomerate or breccia.

In many of its features this group of rocks recalls the Huronian series of Canada, with which its stratigraphical relations would seem to make it equivalent.

LOWER SILURIAN.

This series includes about one hundred and fifty feet of slates (holding *Paradoxides*, *Conocephalites*, *Agnostus* and other *trilobites*, besides several genera of brachiopods), and an overlying mass, measuring not less than two thousand feet, of flags and slates containing *Lingulæ*, worm-burrows, &c. These rocks lie chiefly in a narrow valley, about thirty miles long and four miles wide, between the ridges of Cambrian rocks mentioned above, and to which they are conformable. They are well exposed about the city of St. John, beyond which they extend but a short distance to the westward. Strata of this age also cover portions of the Laurentian rocks north and west of St. John.

The basal portion of this formation, in which alone trilobites have been found, was pronounced by Professor Hartt (in 1865), in a preliminary notice embodied in our report of that year, to be truly primordial, and equivalent to the Etage *C* of Barrande in Bohemia, a conclusion confirmed by Mr. Billings, who pronounced these rocks to be the same with those of the

"Lower Lingula Flags" of Great Britain, and in all probability the same with the St. John Group of Newfoundland, and the *Paradoxides* beds of Braintree, Mass., while they represent an horizon lower than that of the Potsdam of New York. The latter may be in part represented by the upper members of the St. John Group.

UPPER SILURIAN.

Rocks of Upper Silurian age have been recognized by their organic remains at Cobscook Bay in Washington County, Maine, and eastward of Passamaquoddy Bay in New Brunswick. The great metamorphism which these sediments have undergone, and the resemblance borne by many of them to those of the Devonian series, often render their recognition difficult, but about Passamaquoddy Bay, where they are best exposed, and where they mainly constitute the larger islands which here skirt the coast, they appear to consist of a thick series of gray and dark gray, sometimes sandy, shales, black fissile carbonaceous slates, felsites (frequently amygdaloidal), and heavy beds of diorite. They are almost everywhere inclined at high angles.

A mass of gray felspathic slates, diorites and light colored felsites, described in previous publications under the provisional name of the Kingston series, has been supposed to appertain to the group now under consideration. Our present knowledge is not sufficient to enable us, in the absence of fossils, to pronounce confidently as to the age of these rocks, but from the data possessed by us we are inclined to regard them as including both Upper Silurian and Lower Devonian beds, in this respect resembling a portion of the slates bordering the great coal-basin to the north, in which fossils, belonging near the base of the last named group, have been found, and which will be again referred to in the sequel.

From the Devonian series, to which the Kingston rocks bear some resemblance in lithological characters, they differ chiefly in their great uniformity over wide areas; for while the former (as will be presently shown) present very different aspects between the St. John River and the Passamaquoddy area, the latter, from the central portion of King's

County to where they disappear upon the coast, a distance of fifty miles, retain their peculiar features unaltered.

SILURO-DEVONIAN.*

That portion of the metamorphic area in southern New Brunswick not occupied by the rocks above described, consists of Siluro-Devonian strata and granite. Of these the latter forms a ridge of variable width, having Siluro-Devonian sediments on each side. The two together probably occupy three-quarters of the metamorphic country south of the coal-field.

Two principal divisions of these sediments may readily be distinguished on the south side of the granite ridge, viz.: —

		St. John County.	*Charlotte County.*
LOWER DIVISION.	*Lower.*	Limestones, felsites, &c., Conglomerates, local.	Felspathic slates.
	Upper.	Gray sandstones, black slates, "Dadoxylon sandstones."	Gray and black silicious slates.
UPPER DIVISION.	*Lower.*	Conglomerates and diorites, "Cordaite,"	Conglomerates, flags and diorites.
		Fine-grained slates and orthophyre, "do."	Gray and red orthophyre.
	Upper.	Conglomerate and slate. Granitoid grit.	Conglomerate and slate. Gritty felsites.
		Talcoid (?) slates and limestone (thin and perhaps local).	Talcose slates and limestone.

The basal part of the Lower division, which about St. John and to the eastward of it consists of hard conglomerate rocks, is represented in the western part of the county of the same name by felsites, limestones and conglomerate. A projecting ridge of Laurentian gneiss intervenes between the two deposits. Still farther west (as in Charlotte County) felspathic slates are found at this horizon.

Granites.—The mass of granite which extends from the Digdequash River in Charlotte County to the St. John River in Queen's County, is closely connected with the basal portion of this Siluro-Devonian series. These granites rise into hills of considerable altitude, and may be well seen on the Nerepis and Musquash Rivers which cross the middle of the granite range. At the former stream the central portion of the mass consists of fine-grained, tawny felspathic granite or eurite, porphyritic with numerous crystals of felspar and rounded grains of quartz. On either side of this lie coarse red granites, also porphyritic, and holding occasional rounded lumps of gray gneiss and granite, or rarely a boulder of quartz-rock. At this horizon in the granitic mass the rock is often loose in texture and distinctly laminated. This laminated structure results from the presence of numerous parallel planes in the rock, dipping at low angles. It is probable that these indicate half obliterated sedimentary layers, for, on the West Musquash River, the cliffs of this crumbling variety of granite present that irregularity of outline so often seen in sandstone deposits made up of beds of unequal hardness. The highest beds of granite contain but little quartz and mica and thus pass into crystalline felsites.

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* A more extended knowledge of the Devonian rocks than we possessed at the time that our Report on the Geology of southern New Brunswick was written, has led us to modify the classification of this series given there, and in an article on the Azoic and Palæozoic rocks of southern New Brunswick. The fossiliferous portion included in those publications under the name of "Little River Group," is now divided, the "Dadoxylon Sandstone," being associated with the Bloomsbury series under the new designation of the Lepreau division, and the "Cordaite shales" connected with the Mispeck or upper division. All the beds denominated "Upper Bloomsbury" in the older report are included under the head of "Lower Lepreau," and the "Mispeck" of the former publications in like manner is spoken of as "Upper Mispeck."

Age of the Granite.—The section of this mass of crystalline rocks exposed in the Nerepis valley exhibits their relations to the overlying slates very clearly. From the finer granites towards the centre of the mass we pass in descending this river to tawny syenite, with well defined hornblende crystals; this is followed by red syenite, which in its turn gives place to a syenitic rock in which the hornblende does not exhibit distinct crystals, but is in the form of dark earthy spots in the red rock. The deposit which overlies this is one of dark yellowish or reddish crystalline felsite; this differs from the syenite in holding a smaller proportion of quartz, but still contains much hornblende. In the upper one thousand (?) feet this rock is cryptocrystalline. Immediately upon this rests one hundred feet of somewhat slaty petrosilicious rock containing Siluro-Devonian fossil shells. These rocks are covered by one hundred and fifty feet of dark gray crystalline felsite and diorite, which in its turn is overlaid by eighty feet of dark gray silicious slates, holding shells of the same genera as those in the lower beds.

So far as can be judged from the exposures along this valley there appears to be a gradual passage from true granite through felsites to undoubted Siluro-Devonian rocks. Though the same transition has not been elsewhere so clearly marked, yet at several points along the southern border of the granitic area facts may be noted which tend to confirm this intimate relation of the latter to the overlying Devonian strata. On the eastern shore of the St. Croix River in Charlotte County, ten miles above St. Andrews, is exposed a succession of granitoid rocks, resting upon Laurentian gneiss, which both in color and texture recall the granites of the Nerepis range. They are of red or reddish gray colors, often weathering to a bright rusty red, and are, for the most part, an imperfect syenite, containing much red felspar and a soft green uncrystalline mineral allied to hornblende. Portions of the rock are highly epidotic. In descending the river these granitoid rocks are followed by, and seem to pass into, fine dark gray felspathic rocks, which are in turn succeeded by gray felspathic and epidotic sandstones. These latter, like similar beds in Perry, Maine, contain shells of Lingulæ.

On the western side of the river these red granitoid rocks form the major portion of the shore through Robbinston, in Maine. There are two objections to the view that the Nerepis granites are Devonian which may have some weight. In the slate country, between the granite ridge and the Bay of Fundy, where Upper Silurian and Siluro-Devonian strata are upturned, and show their basset edges for many miles, no granitic rocks, or mass of sediments which in bulk and texture would represent them, appear at the base of the Siluro-Devonian. Again, the movements which ensued towards the close of the Devonian age, and in the interval between the latter and the unconformable deposition of Carboniferous sediments, would seem to have found in the area now occupied by the granites a resisting mass, against which the slates were pressed up on either side. Unless then such a barrier were afforded by the Laurentian gneiss, which both in western Charlotte and at Hampstead in Queen's County, are seen to lie beneath the granites of the Nerepis, these latter would appear to have been already metamorphosed and hardened prior to the deposition of the overlying slaty deposits, or if in the condition of ordinary sandstones to have been at least more unyielding than these latter.

The Huronian formation of St. John County has many points of resemblance to the Siluro-Devonian series. A transformation of grits and conglomerates of that series into red syenite was commented on by one of the authors of this paper in a former article.* But these lack the porphyritic structure and coarse texture of the Nerepis granite, and we could find no evidence of the presence of the older series in the tract where these granites occur.

It may be noted as a significant fact in this connection, that at every point but one,† where the border of the granitic mass has been examined, Siluro-Devonian slates have been found to be *next* them, and to dip away from the granitic ridge on both sides. These slates (or petrosilicious rocks) on the south side of the ridge, belong to the Lower Division of the series, so that the granites, if they are altered sediments of the same series, are at the base of this lower division.

It may be noted also, as tending to confirm this view, that *near* the granite in the metamorphic country north of the coal-field, fossil shells have been found indicating an horizon near the base of the Devonian series or at the summit of the Silurian. Should the slates containing these fossils be found to dip *beneath* the granite, which is coarsely porphyritic, and in other features bears much resemblance to the granites of the Nerepis, little doubt of the Silurian age of these latter will then exist.‡

On the whole, the facts thus far known strongly favor the view that the Nerepis granites are altered sandstone and grits at the base of the Siluro-Devonian series.

Dadoxylon sandstone.—In St. John County a part of the

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* G. F. Matthew—Quarterly Journal of Geological Society, Nov., 1865.

† In the exceptional cases referred to the granitic rocks are brought in contact with the Kingston series (Siluro-Devonian ?) by a fault and upthrow of the latter. Opposite to this point (where the granite approaches the Bay of Fundy) the lower beds in the coastal deposit of the Upper Devonian, more nearly resembles granite than elsewhere.

‡ Such would appear to be the case in Nova Scotia, where along the southern side of the Annapolis Valley, a series of slates, holding an assemblage of shells of Lower Devonian aspect, are described by Dr. Dawson as dipping downward towards a mass of coarse porphyritic granite.

Devonian strata have been called the "Dadoxylon sandstones," on account of the numerous trunks of trees of this genus imbedded in the sandy layers. The formation here also contains an abundant and varied flora of the period, as well as remains of insects and crustaceans. Within the county, and for many miles beyond it to the westward, these sandstones are intercalated with slaty beds. Immediately around the sandstone tract these slates are soft, black and carbonaceous; farther to the westward they alternate with silicious layers; and in the Nerepis Hills to the north-west, and about Passamaquoddy Bay to the south-west, the Siluro-Devonian slates, although distinctly banded with alternating gray and black layers, are silicious throughout.

Mispeck Rocks.—In passing upward, from the strata just described, to this division, a decided change may be observed. There is here a return to diorites, conglomerates and bright colored slates, such as may be seen in the lower series. These bright colored rocks are succeeded by pale green slates ("Cordaite"). In the Siluro-Devonian series they are represented by felspathic slates, fine grained homogeneous felspathic rocks, of dark gray (white weathering) and dusky red (bright red weathering) colors, which are often porphyritic with crystals of orthoclase, and become veritable orthophyres, or claystone porphyries, without any trace of lamination, except that in a few places they exhibit distinct bands of color. These colored layers are in the lower portion of the mass.

On the south side of the granitic ridge there is about the middle of this division a group of conglomerates and slate beds, differing from that at the base in the absence of dioritic and other green beds. These conglomerates are covered by a thick mass of altered grits, often granitoid in appearance, but at other times assuming the aspect of coarse talcose and felspathic schist or gritty felsites.

Some impure earthy limestone beds, of no great thickness, with talcose and chloritic slates, are found at the summit of the series.

Conditions of deposition.—It may be inferred, from the nature of the deposits in the Upper Devonian series, that by far the greater part was of littoral origin, or deposited in shallow basins partly shut off from the sea.*

From the Devonian and Siluro-Devonian rocks, to which the above remarks are limited, the slates on the north side of the granite ridge differ in their remarkable uniformity over large areas — a uniformity so great that exposures seventy or eighty miles apart present strata of exactly the same character. In this respect they are more nearly in accord with the Kingston rocks, south of the granite. Although dipping off, therefore, from the latter on the north as the Siluro-Devonian slates do on the south, and though they present a succession of beds parallel to these in general aspect, we do not as yet feel confident in asserting that they are the same.

Granting the Devonian age of these rocks, the relation of the areas north-west and south-east of the granite ridge would appear to have been, as regards the conditions of deposition, very much the same at this time as during the Carboniferous era. In the open basin or pelagic area to the north, the strata present the following succession:

Felspathic eurites, } porphyritic.
Coarse granites, }
Felsites.
1. Dark clay slate or carbonaceous schist.
2. Micaceous quartzite or quartz on mica schist.
3. Fine greenish micaceous slate.
4. Coarse green micaceous slate.

In the slates of No. 1, north of the Douglas Valley in Queen's County, plants which resemble those of St. John have been found. About twelve miles farther east numerous shells, crinoids and some trilobites occur in nearly horizontal beds of gray shale underlying dark gray silicious felsites. To the west fine grained ferruginous gneiss, micaceous quartzite, and mica slates occur in connection with this same division. In these mica slates well defined crystals of *staurotide*, *andalusite* and *garnet* have been developed.

Nos. 3 and 4 are a succession of highly micaceous slates, pale green and argillaceous in the lower part, but of a brighter apple green tint and of a coarser texture in the upper.

Disturbances at the close of the Devonian age. — In the com-

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*The occurrence of land plants in the Lepreau Division on the St. Croix and Nerepis as well as at St. John, together with the occurrence of *Cordaites* through the entire mass of the Lower Mispeck rocks, near the city last named, leave little doubt of the correctness of this view.

position and structure of several of the groups to which the preceding remarks refer, many features present themselves which suggest the latter portion of the Devonian Period, or the interval which elapsed between this and the opening of the Carboniferous era, as having been in this part of the continent one of marked physical changes. Great alterations of level, marked by excessive denudation, had no doubt taken place in earlier periods, as at the close of the Laurentian, and towards or at the close of the Lower Silurian Period, but as the Devonian age was drawing to a close movements of greater magnitude, and involving all the formations of earlier date, would seem to have taken place in this portion of Acadia.

The features to which reference has been made, consist in the metamorphism and debituminization of the sediments, as well as in the extreme plications of the strata, accompanied by the production of a slaty cleavage in the more schistose beds. In these plications the Devonian beds have been affected equally with those of the Cambrian and Primordial, while on the denuded edges of both the Lower Carboniferous sediments rest unconformably. The first indications of these changes which we have are to be found in the passage beds between the Lepreau and Mispeck divisions of the Devonian series. A rapid decrease in the dip of the slates at this horizon, observed at several points in the littoral zone south of the granite range, probably marks the beginning of the great displacements which culminated at the close of this age.

It has already been said that the great gneiss-granite range in the centre of the southern metamorphic belt continued to be a stable area against which the slates were pushed up. This is very clearly seen on its south-east side, where a law of displacement, similar to that traced out by Rogers in the Alleghanies, and by Sir W. E. Logan among the rocks of the Quebec Group, holds. Instances of it may be seen in the eastern part of St. John County, where the lower Cambrian slates are met with on the south-east side of a fold, and the higher beds of the same formation with primordial slates on the other. In the western part of the same county similar displacements may be seen, having the strata uplifted on the south-east side. But the most strongly marked break is one nearer to the granite ridge; this fault runs parallel to it for forty miles, with the Siluro-Devonian slates on the north-west side, and slates of the Kingston series on the south-east.

The same granitic axis has also played an important part in influencing the direction of cleavage planes in the slates. These on both sides of the ridge are parallel to its general course, and dip away from it on each side; even where the course of the slates changes, the direction of the slaty cleavage remains the same, so that masses of the Devonian rocks are sometimes seen in which the cleavage planes cross the strike of the beds at right angles.

THE SILURO-DEVONIAN IN MAINE.

Having found, contrary to expectation, that the rocks in the greater part of the metamorphic country in New Brunswick, near the United States border, are of Devonian age, and since the various bands of slate on the British side have been traced through portions of Maine, by Professor C. H. Hitchcock and others connected with the survey of that state, we venture to offer here some suggestions and conjectures on the probable age of the schists, granites, etc., in the south-eastern half of Maine.

The granite ridge of southern New Brunswick, to which allusion has frequently been made in preceding pages, enters the State of Maine in the township of Calais. It is here represented by a thick body of conglomerate-gneiss (composed of dark syenitic pebbles, from two inches to as many feet in diameter, enclosed in a white granitic, often porphyroid, matrix), dark syenitic gneiss and white granite, which we believe to be Laurentian, and a mass of red weathering coarse granitoid rocks which may represent those of the Nerepis, and perhaps constitute the basal portion of the Siluro-Devonian. Both of these are probably represented in the granitic district of south-eastern Maine, which, according to Professor Hitchcock, is continuous to the sea in the vicinity of Jonesport.

To the eastward of this ridge we appear to have chiefly Siluro-Devonian rocks, with occasional bands of upturned Upper Silurian. The "traps" of this area correspond to the diorites, etc., at the base of the upper division, and the "red jasper" to the red felsites and orthophyre above them. It is probable that the lower division will be but meagrely represented, and the upper half of the upper division wanting in this tract, such being the case around Passamaquoddy Bay.

On the north-west side of the granite ridge noted, we again meet, in New Brunswick, Devonian slates, now in their pelagic aspect. On the Maine border, above Baring, these consist of fine-grained gray gneiss and micaceous quartzite, the former dipping towards and abruptly meeting the gneiss conglomerate above alluded to, within which along the line of junction small pieces of the Devonian gneiss are imbedded, as though fragments of the latter had sunk in the pasty mass.* Farther north these Devonian beds are folded and dip northward, passing beneath a heavy body of fine greenish and grayish micaceous slate, which here represent, perhaps, some portion of the Siluro-Devonian series.

A similar arrangement is indicated by Professor Hitchcock, who represents the slates or schists north of Baring as lying in a basin between the granitic ridge above named, and another which crosses the northern part of Washington County, and is supposed to connect through the northern part of Hancock County with the granitic masses around Mount Desert on the coast. On the southern side of this last granitic ridge, and forming the northern side of the trough are a series of beds, described as quartz-rock and calciferous mica schist, and which are said to be the same as those known to extend through York County, N. B., towards the Bay de Chaleur. This belt of rocks has been recognized, with essentially the same features, by one of the authors of this paper, on the St. John River above Fredericton, and about Grand Lake in the eastern Schoodic region, in the State of Maine. As observed by the latter, it consists of clay slates† and thick intercalated beds of quartzite, etc., rather than of mica schist, and if, as may be the case, it here represents the rocks of the Lower Devonian series, it more nearly resemble these as seen near St. John than those above alluded to as forming the southern side of the trough now under consideration.

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*Dr. Dawson, in his "Acadian Geology" (2d ed., p. 499), describes a similar occurrence in the case of the Devonian rocks on the south side of the Annapolis Valley. These slates, holding fossils of Lower Devonian aspect, are described as dipping into a great mass of white granite, the slates near the junction having been turned into gneissoid rock holding garnets, while numerous angular fragments are enclosed in the granite, which also sends veins into the slates.

†It is in this band of slates that fossils of Devonian aspect have been obtained by Mr. C. Robb, north-east of Fredericton.

The granites on the north side of this basin, both in New Brunswick and Maine, are coarsely porphyritic. They have recently been examined on the St. John River, where along their southern border they are of a reddish tint, containing both orthoclase and albite or oligoclase. Farther north the rock is of a lighter color, consisting of a gray granite (with white orthoclase and black mica), and sometimes contains masses of dark micaceous quartzite. At several points it is overlaid by gray gneiss, holding bands of micaceous quartzite, which also constitute the rocks first seen on the northern slope of the granitic mass. These may be the "argillo-micaceous schists," described by Professor Hitchcock as holding a similar position in Maine, and which are said to extend in an "essentially unaltered form to the Saco River," in fact nearly reaching the south-west corner of the State. At this end of the basin, where probably the lower beds are exposed, the rock contains garnets, *staurotide* and *kyanite*. Along the north-east side (in Northport) it holds *andalusite*. If these rocks represent here the lower part of the Devonian slates, as the mica schists holding a similar position and containing the same minerals do in the central parts of Charlotte County, the geology of this portion of America will be greatly simplified.

There is a belt of granite associated with masses of obscurely stratified gneiss and beds of pyritiferous mica-schist, extending along the coast of Maine, from Portland eastward to the mouth of the Penobscot River, which, as described in Professor Hitchcock's Report, resembles the Laurentian series of New Brunswick. With this exception and possibly that of the belt of slates and quartzites* which skirt the southern edge of the northern granite belt, nearly all the formations of south-eastern Maine might, on lithological grounds, be compared with those of the Siluro-Devonian and Devonian series in New Brunswick. Among these, however, may be islands or ridges of older rock, as is probably the case at some points along the eastern border.

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* A boulder composed of rock, not distinguishable from these quartzites, has been found by Mr. Charles Robb, near the Eel River in York County, which contains several unmistakeable fragments of graptolites. Should these be found to characterize this belt, the latter would of course be referred to the Lower Silurian, which as seen in St. John, they resemble quite as closely as they do the Devonian.

One object in preparing these remarks has been partly to enable New England geologists to test the value of our work in New Brunswick, bearing on the geology of Maine. As it may assist in the discovery of organic remains in the Devonian rocks of that State, we may add that with us the Mispeck division is almost devoid of such, so far as we know, except to the eastward of St. John, where plant remains occur sparingly in the lower half ("cordaite shales"). The Lepreau division is the great repository both for these and for marine organisms. Plants are more abundant in the upper and more silicious half (equivalent to the Dadoxylon sandstone), and shells with a few plants in the lower.

It may be inferred that the discovery of such remains in the metamorphic tracts of New England is not improbable, from the fact that they are met with in New Brunswick, only a few miles from points where the slates are so highly altered as to be filled with crystals of andalusite, staurotide and garnet.

NOTE.

It is proper to add here that the foregoing article will be found to differ in several particulars from that presented and read under the same title, by one of the authors, at the meeting in Salem. The alterations referred to have been deemed necessary from the result of further investigation of the fossils upon which some of the conclusions therein given were based. At the date of the preparation of the original article these fossils were regarded by a competent authority as probably Upper Devonian, and this age was accordingly assigned to the whole of the associated strata. Having, however, since discovered, at the base of the strata thus designated, beds which contain forms apparently of Upper Silurian type, we have given this assemblage of beds the more comprehensive title of "Siluro-Devonian," intending thereby to indicate a geological horizon near the junction of these two formations, and including therefore both Upper Silurian and Lower Devonian forms of life.

It will follow from the same fact, as indicated above, that the Nerepis granites, before looked upon as probably Lower Devonian, must now be regarded as of Upper Silurian age, if not of still greater antiquity.

Lists of the fossils referred to above, with more detailed descriptions of the formations in which they occur, will shortly appear in the Reports of the Geological Survey of Canada. — *L. W. Bailey*, *April*, 1870.

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3. ON THE VALLEY OF THE AMAZON. By JAMES ORTON, of Poughkeepsie, N. Y.

FROM the Atlantic shore to the foot of the Andes, and from the Orinoco to the Paraguay, stretches the great valley of the Amazon. Its area, of two millions and a half square miles, would contain the basins of the Mississippi, the Danube, the Nile and the Hoang-Ho. It lies between three grand elevations: on the north are the highlands of Guiana; on the south rise the table-lands of Matto-Grosso; on the west stand the Andes. The valley begins at such an altitude that on the westernmost edge vegetation differs as much from the vegetation at Para, though in the same latitude, as the flora of Canada from the flora of the West Indies. The greater part, however, is an extensive plain very slightly inclined towards the Atlantic.

From the mouth of the Napo to the ocean, a distance of 1800 miles in a straight line, the slope is one foot in five miles. Professor Agassiz gives the average slope as hardly more than a foot in ten miles; but this is based on the farther assertion that the distance from Tabatinga to the seashore is more than 2000 miles in a straight line. It is not 1600. At Coca, on the Napo, the altitude is 850 feet, according to my own observations; at Tingo Maria on the Huallaga, it is 2200 feet, according to Herndon; at the junction of the Negro with the Cassiquiari it is 400 feet, according to Wallace, and at the mouth of the Marmoré it is 800 feet, according to Gibbon;

while at the Pongo de Manseriche, where the Amazon leaps from the Andes for the last time, the altitude is 1600 feet, according to Humboldt.

These barometrical measurements represent the basin of the Great River as a trough lying parallel to the Equator, the south side having double the inclination of the northern, and the whole narrowing and gently sloping eastward. Furthermore, the channel of the Amazon is not in the centre of this basin, but lies to the north of it. Thus the hills of Almeyrim rise directly from the river, while the first falls on the Tocantins, Xingu and Tapajos occur nearly 200 miles above their mouths. The rapids of San Gabriel on the Negro are 175 miles from the Amazon, while the first obstruction to the navigation of the Madeira are 100 miles farther from the Great River.

No region on the globe of equal extent has such a monotonous geology. On the north is the low, level water-shed between the Amazon and Orinoco, composed of granite and gneiss slightly covered with debris; there is a total absence of sedimentary rocks.* On the south is the high plateau of Brazil, consisting of horizontal strata of palæozoic age, nowhere covered by secondary or tertiary deposits.† On the west are the porphyritic peaks of the Andes. Around the rim of the basin are the out-croppings of a cretaceous deposit; this is the first chapter in its known geologic history. But above this, lining the whole valley from New Granada to the Argentine Republic, are the following formations:

First, a stratified accumulation of sand; second, a series of laminated clays of divers colors and generally without a pebble; third, a fine, compact sandstone; fourth, a course, porous sandstone, highly ferruginous; and finally, over the undulating surface of the last, there was left an ochraceous, unstratified sandy clay, resembling in composition the inundation mud of the Rhine and Nile. The total thickness of these beds cannot be less than 1000 feet. The ferruginous sandstone alone is over 800 feet thick; but the table topped hills of Almeyrim are almost the sole relics. If the plausible theory be true that these are the mementoes of a colossal denudation, the history of the Amazonian Valley is quite different from that

* Evan Hopkins, F. G. S.

† Dr. Lund.

of the Pampas where there is no evidence of much superficial denudation. The trend of these hills, east and west, would indicate that the denuding force came from the Andes.

It is a question to what period this vast accumulation is to be assigned. The earlier observers pronounced it of marine origin, Humboldt calling it Old Red Sandstone, and Martius, New Red. It can be neither of these, for it overlies the cretaceous. Professor Agassiz gives it a post-tertiary date and fresh-water origin. It is "drift (he says), the glacial deposit brought down from the Andes and worked over by the melting of the ice which transported it." The Professor farther declares that these deposits "show no sign whatever of a marine origin; no sea-shells nor remains of any marine animal have as yet been found throughout their whole extent; tertiary deposits have never been observed in any part of the Amazonian basin." In the words of Mr. Lyell: "Professor Agassiz has hazarded the startling conjecture that the Amazonian basin was closed up and converted into a lake by the terminal moraine of a glacier which stretched for thousands of miles from west to east and entered the sea under the equator. But this distinguished naturalist, Lyell continues, candidly confesses that he failed to discover any of those proofs which we are accustomed to regard, even in temperate latitudes, as essential for the establishment of the former existence of glaciers where they are now no more. No glaciated pebbles, or far transported angular blocks with polished and striated sides, no extensive surface of rock, smooth and traversed by rectilinear furrows, were observed" *

It is true that neither Bates, Wallace nor Agassiz found any marine fossils on the banks of the Great River. But these explorers ascended no farther than Tabatinga. Two hundred miles west of that fort is the little village of Pebas at the confluence of the Ambiyacu. In December, 1867, it was my fortune, in coming down from the Andes by the Rio Napo and Maranon, to stop at this place. In the high bank on which the village stands, I discovered a fossiliferous bed interstratified with the variegated clays so peculiar to the Amazon. It was crowded with marine, or at least brackish-water shells! They belonged to the genera *Neritina*, *Turbonilla*, *Mesalia*, *Tellina* and the new genus *Pachydon* resembling Isocardia. They were all new species, excepting a *Neritina pupa*, which, by the retention of its peculiar markings and by its being a living West Indian species, points to a recent era. I may add, that a sample of the red clay from a different locality, was examined under the microscope at my request by Professor Clark, who reported "fragments of gasteropod shell and bivalve casts." Moreover, mingled with the clay deposit along the river are seams of a highly bituminous lignite. I traced it from near the mouth of the Curary on the Napo to Loreto on the Maranon, a distance of about 400 miles. It also occurs at Iquitos, where it is used as fuel.*

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* Lyell's *Principles*, I, 468-9.

From these facts, I infer: first, that the Amazonian clay formation cannot be referred to the ice-period, but is late tertiary, and like the Pampean mud may be an estuary deposit; second, that we have some grounds for the supposition that not many ages ago there was a connection between the Caribbean Sea and the Upper Amazon; in other words, that Guiana has only very lately ceased to be an island. Corroborative of this is the fact that there is no mountain range on the water-shed between the Orinoco and the Negro and Japura, but the three rivers are joined by natural canals; third, that in tertiary times, a shallow sea separated into islands Guiana, Brazil and the Andes, and that the mediterranean portion, where now lies the Amazonian basin, was rendered brackish by the influx of fresh-water from these highlands; that the moment the slight elevation took place between Guiana and the Andes, and Brazil and the Andes, the accumulating floods were turned eastward and ploughed a deep channel which is now called the Amazon. The fine laminated beds show that they were deposited in quiet waters which became turbulent as they became shallow as indicated by the coarse sandstone on the top of the series.

But "it is contrary to all our knowledge of geological deposits (says Professor Agassiz) to suppose that an ocean basin of this size, which must have been submerged during an immensely long period, in order to accumulate formations of such a thickness, should not contain numerous remains of the animals formerly inhabiting it." To this objection I reply that the paucity of shells is as remarkable in the similar deposit on the Rio Plata, and farther, that negative evidence is no evidence at all. To quote the language of Mr. Darwin, the discovery of the Pebas shells "is one more most striking instance how rash it is to assert that any deposit is not a marine formation because it does not contain fossils."

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* Mr. Huxwell has since found many more fossil shells in the south banks of the Maranon, thirty miles below Pebas, and the natives say they occur also at Ornaguas and up the Ambiyacu.

4. THE PLASTICITY OF PEBBLES AND ROCKS. By WILLIAM P. BLAKE, of San Francisco, Cal.

AT the Newport meeting of this Association in 1860, the attention of the members was directed by Mr. Charles H. Hitchcock to the peculiar elongated structure of the conglomerate at Purgatory.* In that communication and in a subsequent elaborate paper by the late Professor Hitchcock, published in the "American Journal of Science,"† it was maintained that the pebbles composing the Newport and other conglomerates had been elongated, compressed and distorted by tension and pressure after having been rendered plastic by an elevation of temperature.

Objections were made at the Newport meeting to this view of the origin of the structure, one eminent geologist and physicist, Professor Rogers, arguing that these pebbles had not been drawn out, that their original forms as deposited had not been changed, but that their peculiar elongated forms were due entirely to their having been moulded by wave action out of oblong fragments of the original metamorphic rocks.

At subsequent meetings the subject has been more fully discussed, and there yet appears to be considerable difference in opinion among geologists, upon the origin of this peculiar elongated and flattened structure. Other localities have been noticed in Vermont* and in Maine,† and I now present some fresh evidence from the distant regions of Arizona and California upon this interesting question.

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* "Geology of the Island of Aquidneck," Proc. Amer. Assoc., xiv, 1860.

† Amer. Journ. Science [2], xxxi, 372, May, 1861.

In Arizona Territory, near La Paz upon the Colorado River, there are extensive outcrops of a conglomerate made up of a paste of micaceous schist filled with pebbles of granular quartz, varying in size from an inch, or less, in diameter to masses weighing many pounds.

These pebbles, in general, present phenomena of elongation and compression similar to those of the Newport conglomerate. They give even more conclusive evidence of having been drawn out and compressed.

Elongated forms, with flattened drawn-out ends, blending at times with the mica schist are most common. The pebbles generally separate easily from the matrix and the ground is covered with those that have been detached by weathering, and which are now mingling with the modern alluvial drift. All these pebbles are uniform in texture and appear to have originally been much water-worn and well rounded by attrition. Some of the pebbles show that they have been broken across in several places, in different directions, and that the fragments have been reunited or reconsolidated as strong as before.

I was formerly skeptical in regard to the asserted distortion and plasticity of the Newport pebbles, and favored the explanation that the elongated forms were produced by wave-action, but the examination of the Arizona conglomorate convinces me that not only it, but the Newport conglomerates, and those of many other localities, have been distorted and drawn out and compressed. I am sure that the examination of the outcrops would satisfy even the most skeptical.

But the evidence of distortion of hard rocks on the Pacific Coast does not rest with the Arizona conglomerates only, it is found on a large scale upon the flanks of the Sierra Nevada of California. Those who have ascended the lower slopes of the range in the gold region are familiar with the remarkable outcrops of slates well described by the name of "gravestone slates," given to them by the miners from their resemblance to gravestones. They stand above the earth in long lines, like tall tomb-stones, and are sometimes ten or fifteen feet high, and are not over three or four feet broad at the base.

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* By Professor Hitchcock. See Final Report upon the Geology of Vermont.

† By Professor Charles H. Hitchcock. Preliminary Report upon the Geology of Maine, 1861. The distortion of rigid pebbles appears to have been noticed by Professor Edward Hitchcock, as early as 1833. See Report upon the Geology of Massachusetts.

These slates vary in composition; some are like roofing slate, others are arenaceous, and some are semi-metamorphosed conglomerates with small pebbles. They are principally of the secondary period.

An examination of these remarkable slates shows that their peculiar form is due to the elongation of the grains which compose them, and consequently of the whole mass. The conglomerates show the elongation with the greatest distinctness. In some outcrops pebbles appear to have been stretched as much as twice or three times their original length or diameter. They are not only drawn out but flattened so as to become long lenticular masses, thus giving a slaty structure to a rock originally made of rounded pebbles. Examples might be multiplied almost indefinitely. Vast masses of rock have been thus acted on, and this drawing out and elongation of mountain masses of rock is more common than has been generally supposed.

All these phenomena indicate that the flexure or folding of rocky strata on a large scale must give rise to great tension upon the outer curve of the bend. Professor Hitchcock supposes the tension by which the rocks were elongated to have been produced in this way in some cases. He remarks also, that the Vermont rocks appear to be stretched in the direction of the dip, while at Newport they are elongated horizontally. Nearly all the examples in California show the elongation to be in the direction of the dip. But I believe the rocks to have been subjected to a much greater elongation than can have been given by any folding. I regard them as having been subjected to direct tension over large areas, and generally in vertical or highly inclined planes. Moreover, these elongated masses do not appear in such positions that we can regard them (at least in most cases) as forming portions of great anticlinal arches. They may form the sides of great synclinal troughs and have been under great tension during subsidence of a mass of formations in the centre of the trough.

It may here be observed that this great elongation of rock masses, and the flattening of all the grains of sand and of pebbles which compose them (an elongation in some cases to twice or three times their original length), has been accomplished at the expense of their thickness. Thus strata so elongated are much thinner than in their unstretched condition. This is a consideration which bears directly upon the discussion of the probable height of anticlinal folds.

With regard to the condition of the quartz pebbles, and of the rocks during the process of elongation, there is room for wide speculation and a variety of hypotheses. Scrope, Beaumont, Scheerer, Hunt and others, maintain that all the deep-seated rocks become plastic. We cannot, of course, easily conceive how this distortion of the hard pebbles could have been effected when in their ordinary condition. That rocks are much softer in the bed or quarry than after they have been raised and exposed to the air, is a familiar fact to all miners and quarrymen. This softness of rocks may perhaps be, and probably is, increased by an elevation of temperature. We may legitimately invoke the agency of heat and water to aid us in accounting for these interesting phenomena, but I conceive that it is not necessary for us to believe that these changes of form were effected at very elevated temperatures. There does not appear to have been anything like semifusion or viscidity of the mass, and when I use the term *plasticity* I do not connect with it the idea of any great softening produced by heat. The consideration of the phenomena leads me rather to the conclusion that enormous and long continued pressure and tension, at a moderate elevation of temperature, perhaps (but not necessarily so), have been sufficient to produced the molecular movement of these hard and apparently unyielding materials. Water permeating the mass, or the vapor of water, may faciliate this movement, but there does not appear to me to have been any condition involving a great chemical change. The evidences of such changes are wanting. Mechanical force alone appears to have been the agent. This I not only consider to have been the cause of the distortion of pebbles and rocks, but to have been sufficient to reunite fragments of pebbles or rocks so as to make them homogeneous. This may be by some considered as an example of cementation by solutions — a kind of rock regelation — which certainly might occur and probably does, but we are not precluded from the conception of the possibility of the fragments being reunited simply by pressure, when under favorable conditions. I may here refer, in support of this view, to the beautiful experiments made by Mr. Hungerford at the Chicago meeting, in reuniting the fragments of ice when at such a low temperature as to preclude the idea of there being any fusion of the contiguous surfaces of the fragments. Examples of the mobility of the particles of metals at our ordinary temperatures are numerous and familiar.

Lead at a temperature below fusion is forced by hydraulic pressure into pipe; every coin and medal has been moulded by pressure, and iron may be forged or drawn into wire either hot or cold. Tersca* has shown that under enormous pressures solids can be made to flow in the same manner as liquids or that in their movements they follow the same law. If a strong cylindrical mould be taken, open at one end and partly closed at the other, discs of iron placed in it may be forced out of the small opening by powerful pressure from a follower or piston in the cylinder, and these discs are changed into cylinders or a mass of elongated cones. It may here be observed, incidentally, that in this we appear to have a direct illustration of the mode of formation of the curious forms found in rocks called stylolites, and of those generally known as "cone within cone," described by Professor Marsh at the Burlington meeting, the former of which was regarded by him as the result of pressure, and the latter of pressure on concretionary structure when in process of formation, while the rocks were soft or in a plastic state. The distortion of fossils is another familiar example of rock plasticity. Tyndall, in the appendix to his work upon the "Glaciers of the Alps," expresses the opinion that a mass of solid glass may, by pressure, be forced to permanently change its form, and that some rigid pebbles of quartz, in the Museum of the Government School of Mines, have been squeezed by enormous pressure against each other so as to produce mutual flattening and indentation. We have also an example in the columns of the House of Representatives, quarried on the banks of the Potomac, where the calcareous pebbles appear to have been forced by pressure one into the other. Professor Ramsay described the pebbles in the Museum of the Government School of Mines, as from three to nine inches in diameter, and he thought that the indentations were produced by wearing or the rubbing of one pebble against another while under great pressure, and perhaps partly by the aid of intervening grains of sand. Mr. Sorby regards the interpenetration or impressment of pebbles as due to mechanical and chemical agencies combined, and cites the fact that in the majority of substances mechanical pressure increases their solubility.

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* Mémoire sur l'éconlement des corps solides soumis à de fortes pressions par M. H. Tresca, Compte Rendus, T. LIX, 1864, p. 754.

Such explanations are not satisfactory for the Arizona conglomerate. Mechanical pressure and tension alone appears to me to have accomplished the result. This also appears to me to be the most satisfactory explanation of all other examples that I have seen. There does not appear to have been any solution, or at any rate not sufficient to affect the form and surface of the original pebbles. The Arizona pebbles are almost as clean and smooth as if just out of the bed of the brook. They separate readily from the lamellar part of the rock. They are not cemented to it as would probably be the case if they had either been softened by great heat or partly dissolved or acted upon chemically. So also in the case of the large masses of rock, the outlines of the small pebbles do not become obliterated although the form is so much changed that they can hardly be recognized as having been originally in the form of pebbles.

In these phenomena we see how a rock which was originally granular and made up of pebbles may become entirely changed in structure. Deposited as a conglomerate it may become a lamellar slaty mass extended in one direction to twice its former linear dimensions. It will split up or cleave easily in one direction and not in another, and will weather unequally as we find in the sharp outcrops of gravestone slates of

California. The same elongating and compressing forces applied to finer sediments must of necessity greatly modify their structure and cleavage, but the change of texture, owing to the fineness of the particles, does not become visible to the eye. By the careful study of these phenomena of plasticity new views are opened to us of the structure of great rock-masses; of the phenomena of plication, of lamination and of the origin of some structural peculiarities of mineral veins and their inclosing walls. In view of all the facts I think that geologists should be more willing to admit that very great changes have been produced in the structure of rocks and rock-masses by simple mechanical force unaided by any great elevation of temperature or by extraordinary chemical agencies.

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5. On Some Recent Geological Changes in North-eastern Wisconsin. By G. R. Stuntz of Lancaster, Wis.

[Communicated orginally, March 12, 1854.]

This is the second season I have spent in this new and but partially explored region. In the summer of 1852, I arrived on this part of the lake, with a party of twelve men, for the purpose of extending the Surveys of the United States bordering upon the south-west coast: and, also, of running the boundary line between the State of Wisconsin and the territory of Minnesota. Since the completion of those works I have been voyaging in all directions through this country and between the lake and the Mississippi River. The peculiarities of this lake are fully described by Foster, Whitney and Dr. Owen, in reference to tides, in their able geological reports; also to a change of water-level in the lake. I would here state that since my arrival at the mouth of the St. Louis River, in July 1852, the water of the lake had fallen, and was on the first of November, 1853, twenty inches lower. This is probably the periodical change of level. There is another change of level apparent, which I do not recollect having seen noticed in any report. That is the gradual rise of water at this end of the lake, and the falling of the same at the east.

The mill race at the falls of the Ste. Marie River, only a few years since, was used by good sized Mackinac boats as a canal in making the portage around those dangerous Rapids. In the summers of 1852 and 1853, this mill race was entirely dry, which fact is referred to by J. W. Foster in his able report. The wearing away of the channel, upon a hasty view of the subject, would be the natural conclusion, but the facts do not warrant it. Should the tributaries that pour an unceasing tide be cut off, except enough to counteract evaporation, and should the river Ste. Marie continue to discharge the same volume as at present, which is about one billion, eight hundred and forty-eight million, three hundred and twelve thousand cubic yards per year; and should Lake Superior be allowed to contain thirty-two thousand square miles, it would take over fifty-three and a half years for the lake to fall one yard, which is about the original depth of the mill race before referred to; and this is a much longer period of time than has transpired since that race was used for the purposes before mentioned.

The small stream at Pindell's mill, a few miles above Jaquois Point, runs with a rapid current to the lake, having no marshes, and not widening nor giving any indications that its valley is overflowing by the lake setting back into it, but on the contrary the formation of sand about the mouth indicates a gradual receding of the waters of the lake. As you go westward, the Ontonagon River exhibits a slight filling up. The valley near the mouth shows that at the time it was excavated the surface of the lake was lower than at present. The same is also apparent at the mouth of Bad River still farther west.

At the mouth of Bois Brulé the same thing is exhibited, only to a greater extent. From this to the west end of the lake not only does the lake set back into the valleys of the streams, but the waters are making rapid encroachments on the banks. So rapidly is the filling back, that the deposits of the streams do not keep pace with the filling up. The consequence is, that there is a large marsh and pond in the mouth of the valley of Bois Brulé and Aminecan River. But nowhere is this filling up more apparent than in the bay above the mouth of the St. Louis River. In several parts submerged stumps, several feet below the present water level, are found. The numerous inlets surrounding the main bay, when we consider the nature of the soil and the formation (a tough red clay), in all of which the water is deep, could not have been excavated in the natural course of events with the water at its present level. The testimony of the Indians also goes to strengthen the same conclusions. At the time of running the state line above mentioned, the Indians, ever jealous of their rights, called me to a council to inquire why I run the line through Indian land. In the explanation, I gave, using the language of the law as a starting point, the lowest rapid in the St. Louis River. The chief immediately replied, that formerly there was a rapid nearly opposite the Indian village. Start, said he, from that place and you will be near the treaty line. After he had been farther questioned I learned that it was only a few years since the river was quite rapid at the Indian village. At the time the said line was run the first rapid was about one mile by the stream above the village. From these facts, I conclude that a change is taking place gradually in the level of this great valley. This change may lead in time to as important results in changing the geography of the country as have taken place within a comparatively short period of time in the valley of the St. Croix. The St. Croix Valley is about forty miles in diameter north and south, and about one hundred, or one hundred and twenty miles, east and west, surrounded, or nearly so, by ranges of trap hills, which attain nearly a uniform height of six hundred feet. These time enduring barriers withstood the warring of the elements until within a few centuries past, when some change, probably not unlike the above, assisted them in breaking away at the falls of that river, discharging a volume of water through that narrow gorge, which in its native serenity, crystal purity, and quantity, would vie with any of the great sisterhood of lakes. But it has gone foaming and tumbling to the Gulf of Mexico, and we can only read traces of its onward flight in the numerous terraces along the river banks below, and the excavation of Lake St. Croix and Lake Pepin, and the piling of terraces along the father of waters as low down as the mouth of the Missouri.

In the valley above the falls you find, what you would expect to find, after the lapse of a few hundred years should any convulsion of nature change the valley of any of the great lakes to dry land, extensive sand planes, slightly timbered with stunted pines. There are exceptions, it is true, but the line of demarkation is as plain as though the event of draining took place only last year. What is called Wood Lake timber, is a narrow belt of elevated timber land, extending from the south-east side of the valley towards and nearly to the mouth of Kettle River. This ridge, having a good soil of clay and loam resting on a sub-soil of sand and gravel, from its elevation must have been drained at a much earlier day than the balance of the valley.

On all the streams, so far as I have examined, these appearances are the same. Standing at a point a few miles to the north-east of the mouth of Wood River, you are near the centre of a system of rivers coming from all the points of the compass, except the great outlet on the south, Upper St. Croix on the north-east, Namekagon on the east, Yellow River, Clam River and Wood River from the south-east, the first of these last three flowing through a chain of lakes of some twenty miles in extent, containing white fish in abundance. On the south-west come in Sunrise River and one or two smaller streams, from the west Snake River, and from the north-west and north Kettle River and several smaller streams. These streams; flowing from the high rocky barrier before spoken of, present a variety of scenery and a variety of soil alike interesting and valuable.

In connection, it might not be out of place to remark that other facts present themselves to the mind of the student of nature, intimately connected with the above.

Throughout the great valley of the Mississippi and bordering upon many of the great lakes are found mounds and tumuli, evidently the work of men's hands:—the labor of a race long since passed to oblivion, except as yet this single trace of their existence. That they were a numerous race these mounds plainly indicate. That they were skilled to some extent in the arts, their mining operations at Ontonagon on this lake, near the Minnesota Mining Co.'s works, plainly prove. That they were the same people that inhabited the

Mississippi Valley, the various implements would also indicate. I have in my possession a stone hammer which I found at the ancient copper diggings near Ontonagon, and I have seen similar ones obtained in the vicinity of ancient mounds at Rock Island, Illinois.

This people, whoever they were, occupied or built their mounds, for whatever purpose they were erected, upon the finest sites the country afforded. You will find them on the finest situations for building along the great rivers, and on elevated localities commanding the finest views of the surrounding country. This is particularly remarked by every traveller on the Upper Mississippi, and the St. Croix below the falls.

As you ascend this last mentioned stream, a short distance above Moriere, you find several unusually large mounds in a small plain, elevated some sixty, perhaps one hundred feet, above the river. Thence following the river you pass the rocky gorge or Dalles and enter the valley of St. Croix above the falls. The same beautiful river rolls at your feet, and in going up a succession of banks, grassy slopes greet your sight; but the mounds are not there, and, for the distance of seventy-five miles by the stream, I have looked in vain for these relics of that obliterated people.

At the mouth of Yellow River they are again found, occupying, as before, the most beautiful sites the locality affords, and at an elevation nearly equal to the southern rim of the basin. From this point nearly in a straight line and lying intermediate with the falls of St. Croix, are situated Yellow Lake, Clam Lake and Wood Lake, all occupying elevations nearly equal to the rocky barrier over which the waters were formerly discharged at the falls before mentioned. At each of the two last mentioned lakes a single mound of the same description occupies a prominent place in the delightful scenery of the lake. At Yellow Lake, the most attractive of the three, they are found in great numbers, extending down the river several miles, but in every instance occupying the highest elevations. In my examinations on two trips through this ancient lake-bed, I have failed to find any mounds on lower situations than those above described.

Then if this view should not be proved incorrect, we have one geological event coupled with the operations of this ancient people. And we cannot avoid coming to the conclusion that these mounds were built prior to the wearing away or breaking down of the falls of St. Croix, and that the trip from the Mississippi to Lake Superior was one of ease and pleasure compared with the journey of the present day through almost impenetrable forests. I hope some one better prepared to carry out and systematize a series of observations may profit by the above.

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6. The Gems of the United States. By Dr. A. C. Hamlin, of Bangor, Maine.

With the exception of the emerald, all of the gems in more or less perfection are found within the limits of the United States. The diamond has been discovered in California, among the Rocky Mountains and along the gold belt which extends from Central Alabama through the Atlantic States to Maryland. In Alabama, Georgia and the Carolinas the itacolumite, which has been regarded as the matrix of the diamond in the Urals, Brazil and Hindostan, appears in extended ledges, and even rises to the magnitude of mountains. In 1866, while exploring the auriferous regions of Alabama and Georgia, I recognized this rock in many places, especially near Gainsville, where it crops out in great ledges.

Diamonds have been found along the course of the itacolumite, especially near Gainsville and farther to the north-east, at the Glade and Horshaw gold mines. Some of these stones were of several carats weight and of fine water. One of these which had been polished in London was shown to me at Gainsville, and it is a gem of the purest water. From information obtained from the residents of these regions and from personal examination of the localities, I have but little doubt that active research with the application of skilled labor [for the diamond is not easily recognized in its rough state], will bring to light many fine stones. A splendid stone was destroyed by the stupidity of the laborers at the Horshaw mines a few years ago. A beautiful gem of 24 carats was found in 1856, near Richmond, Va.

The garnet is found in many of the States, and of sufficient purity for the purposes of the lapidary. At Fitchburg, in Massachusetts, beautiful little pyropes are found in the alluvial sands. In Delaware County, Pennsylvania, pyropes of larger size, but of less beauty of color, are also washed out of the alluvial soils. All along the Rocky Mountain slope clear garnets have been observed. In the sands of New Mexico the Indians find garnets of considerable size and equal to the best of the Syrian stones, exhibiting the crimson and violets tints of the oriental garnets. At Pike's Peak, in Colorado, garnets of less size, but of even finer tints, are washed out of the gravel beds by the gold miners. These are the finest of the species in America, and with the exception of the rubellite, they approach in color nearer the ruby than any other stone. Beautiful cinnamon garnets occur at Phippsburg and Parsonfield, Me., Warren, N. H., and in many other places in the States, but they are rarely sufficiently perfect for ornaments.

Chrysoberyl is found at Haddam, Ct., in New York, Vermont and in Maine, but few transparent crystals have yet been discovered. Spinel occurs in New York and New Jersey, but the crystals are generally opaque. Zircon is widely distributed in the States, generally massive and opaque. The finest crystals come from Buncombe County, North Carolina. The iolite, known as the sapphire d'eau of Ceylon, has been found at Haddam, Conn., and in other places in New England, but fine specimens are quite rare. It is often pleochroic, exhibiting different colors when viewed in different directions. The topaz occurs at Trumbull and Middleton, Conn., and in North Carolina, but the colors are generally very faint, and transparent specimens too small for the purposes of the lapidary. The amethyst is found in rare perfection in various parts of the United States. Oxford County, in Maine, Berlin Falls, in New Hampshire, and Bristol, R. I., furnish beautiful specimens. Fine stones are found in Delaware County, Pa., and at Kewanan Point, Lake Superior, but they are more plentiful in Georgia than in any other State. Several varieties of opal are found in the United States, but none of good quality like the precious and fine opals of Mexico.

Sapphires are found in several of the States; at the Chester emery mine in Massachusetts, in New Jersey, in Connecticut, New York, California, Pennsylvania and North Carolina, but they are generally massive and opaque. At El Dorado Bar, in Montana, however, they occur in transparent and well defined crystals of six-sided prisms and also in the amorphous form in the alluvial sand, together with native gold. Crystals of several carats weight have been picked up out of the pan, where they have settled down in consequence of their gravity during the process of washing the gravel for gold. Sapphires of almost all colors have been found there, the red, green, blue, yellow and white, and some of them are of considerable value. They resist the action of the fire and do not change color when exposed to the strongest heat of the forge. No systematic search has been made for these precious stones at this locality, although they seem to occur in abundance. The gold washings of this Bar are now abandoned.

The beryl—the subspecies of the emerald—occurs in many parts of the United States. It has been found in great perfection in the granite hills of Oxford County, in the State of Maine, and more especially in the ledge at Royalston and Fitchburg, in Massachusetts. In gash veins of quartz, occurring in granite in North and South Royalston, beautiful crystals of this gem have been discovered, some of them exhibiting the longitudinal striæ and the aberration of colors which distinguish the remarkable beryls of the Altai Mountains in Siberia. Lively sea and grass green, light and deep yellow; also blue crystals of various shades have been found at this locality. At the quarries at Fitchburg, beryl of a rich golden hue, approaching the chrysoberyl and topaz in color and hardness, and closely resembling the yellow diamond in lustre, have been blasted out. All the deposits where the beryl occurs seem to be very superficial, and at Royalston and Fitchburg the crystals appear to arise from the felspar, becoming clearer and more perfect as they penetrate the quartz. All of the crystals found during my explorations at these localities were thus connected with the felspar. This rule, however, was not observed at Mount Mica, where all the beryls were generally enveloped in quartz or albite, and unattached unless to crystals of muscovite.

Tourmalines of great perfection and variety of colors have been found at Mount Mica, in the State of Maine. This little hill — which is perhaps one of the most remarkable mineral localities on the globe, since nearly forty varieties have been found there within an area of thirty feet square — is one of northern spurs of streaked mountain in the town of Paris, in Oxford County. The mineral deposit was discovered in 1820, by Hon. E. L. Hamlin and Dr. Ezekiel Holmes when students, and whilst searching for minerals. At that time about forty crystals of tourmaline, some of which were quite perfect in form, of fine color and limpidity, were picked up on top of the ledge, or found in the earth which had accumulated around its base. Since this period the place has been visited by mineralogists from time to time and the entire deposit blasted out.

Some magnificent crystals of rare perfection of form and of beautiful colors have been found there. Some of these crystals were several ounces in weight, several inches in length and more than an inch in diameter. Some were red at one extremity and green at the other. Others were red within and green at the circumference. Superb stones of this description and arrangement of colors, but of less size, have also been discovered there, and they called forth the remark from the elder Silliman that they were incomparably fine and without a parallel in the world. Nearly all the varieties of this remarkable gem have been found at Mount Mica, — the clear light green, like those from the dolomites of St. Gothard, the pink of Elba, the white and yellow of Ceylon, the dark smoky green and blue of Brazil, the lighter blue of Sweden, and the fine red and green of Siberia. In some of the crystals the red passes into blue, and the blue into black or into green; in others the white changes into red, green or blue, exhibiting many intermediate shades. Generally the transitions and gradations of color are imperceptible as they pass from one into the other, but in some crystals the line of demarkation is well defined.

The tourmalines of Mount Mica occur in a coarse granite resting upon mica schist, and were probably deposited from above and from solution. The granite appears in layers, and the tourmaline streak penetrates across and through them without any reference to seam. Coarse and opaque crystals of several inches in diameter and nearly a foot in length, are found in the albite and masses of quartz, but all the fine and transparent prisms have been found in cavities whose walls were composed of smoky quartz and albite. In these cavities (which have been found of a size varying from few inches to several feet in length,) the tourmalines appear either loose in the disintegrated cookeite or arising from the interior walls and sometimes penetrating crystals of the matrix. A few feet below the surface the tourmaline streak disappears and the walls show quartz, albite or granite destitute of other minerals. This superficial degree of deposit is not confined to the tourmaline alone but is noticed with most of the other gems.

The sapphire, diamond and emerald are found near the surface, and this rule is well exemplified in the occurrence of the amethyst in the mines along the Rocky Mountain slope, where it vanishes at the depth of ten to twenty feet, although the quartz crystallizes in a colorless state even at the great depth of six hundred feet below the surface. It seems as though the gems required some ray of light or some effect of the atmosphere to build up their forms and perfect their hues. Although it is a common belief that tourmalines are of inferior value, they are not really so, and they should take a high rank among the first of the gems. For none exceed them in the phenomena of physical properties, or in complexity of composition, or in the vast range of their colors; and their hardness is quite equal to the emerald, which they surpass in refractive powers, whilst their dispersive energy exceeds even that of the sapphire and topaz.

There are many localities in the world where this stone is found, but fine specimens are rare, and when they are limpid and approach the emerald, the topaz and the sapphire in hue, they are sold for those gems. The red tourmaline, the rarest of all gems, when free from faults and of fine colors, according to the eminent authority of Professor Beudant of Paris, is sold at the price of the ruby, the most costly of all the gems.

The finest specimens of the tourmaline species known in the world have been taken from the now exhausted locality at Mount Mica. Some beautiful crystals of splendid color have been found in loose boulders at Hebron, Maine, but the parent ledge has not yet been discovered. There are other localities in the United States where these stones occur, but they are opaque or of very poor color and imperfect crystallization.

There is no gem, not even the sapphire, which surpasses the tourmaline in variety of color, and as Barbot has remarked, "it seems as if nature had wished to prove to man that she could imitate quite perfectly that which she had created the most perfect."

The Spaniards, under Cortez, whilst on their march to the capital of Mexico were astonished at the size and beauty of the emeralds and turquoises that decorated the persons of the chiefs who came to join them as allies or visit them as envoys from Montezuma. And after the conquest of the country they sought in vain for the mines whence these emeralds and turquoises came. The emeralds undoubtedly came from Central and South America, and were brought overland or along the coast as an article of trade, since they have not been found anywhere in the United States or Mexico.

The turquoise, the Mexicans said (in reply to the question of the Spaniards), came from the far north, but the mines were not discovered until recent times. The histories of the Spanish occupation of Mexico make no mention of these mines—at least so far as I am acquainted with them. A mine of great antiquity is situated in the Cerillos Mountains, eighteen miles from Santa Fé in New Mexico. The deposit occurs in soft trachyte, and an immense cavity has been excavated by the Indians in past times whilst searching for this gem. Within a few years the Navajo Indians have revealed the existence of a mine in the Sierra Blanca Mountains in New Mexico, but they will not allow strangers to visit it. Stones of transcendent beauty have been taken from it and handed down in the tribe from generation to generation as heirlooms.

Nothing tempts the cupidity of the Indians to dispose of these gems, and gratitude alone causes them to part with any of these treasures, which, like the mountaineers of Thibet, they regard with mystical reverence. The Navajos wear them as ear-drops, by boring them and attaching them to the ear by means of a deer sinew. Lesser stones are pierced, then strung on sinews, and worn as necklaces. Even the nobler Ute Indians, when stripping the ornaments of turquoise from the ears of the conquered Navajo, value them as sacred treasures, and refuse to part with them even for gold or silver. One of these magnificent stones was presented by the Navajo chief to Major-General Carleton, when Governor of New Mexico, and it may be taken as the type of the American turquoises, although there are larger stones in possession of the tribe. It is nearly an inch in length, one-third broad and one-fifth in depth, and equal, in purity and delicacy of tint, to the best of the Persian. Other mines have been reported as occurring along the Rocky Mountain range, but I have not been able to obtain any reliable information concerning them.

7. STUDIES IN CHEMICAL GEOGONY.* IN THREE PARTS. By HENRY WURTZ, of New York.

INTRODUCTORY REMARKS.

THESE being subjects on which volumes might be written, the whole must needs be condensed, on such an occasion as the present, into a few brief notes, more or less disconnected, as I fear; and to views but partially expressed.

I have long held that the principle which should pervade and strictly govern all researches into the chemical conditions prevalent during past geological time, is to seek out the great natural chemical operations prevalent at this day, and trace them back to their necessary spring and beginnings.

It is true that actual laboratory researches into the characters and composition of the products and relics we possess of those far distant times, are as yet wofully deficient, and before the day shall come when the riddles of the past shall be read, and its many mysteries unveiled, in the light of perfect theory, myriads of laborious researches, both analytical and synthetical, must be made; still I believe that enough has already been done in this field to justify some attempts at generalization. And though these be conceded to be pure hypotheses, still the history of science establishes the value of such hypotheses, as starting points, in stimulating discussion and in suggesting modes and subjects of experiment.

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*The following series of notes was prepared to be read at the Chicago meeting, in 1868, and the titles were there announced in the published lists; but as the author was not able to be present then, he preferred to await the Salem meeting.—H.W.

I. ON THE PROZOIC ATMOSPHERE AND THE OCEAN OF THE ZOIC DAWN.

It cannot be doubted that it was during the time of the deposition of the earliest sediments of the ocean, which are known to us now only in the forms of compacted and crystallized metamorphic masses, that life began, and that it had its beginnings in the waters of the ocean. The exterior Ocean of Atmosphere, though supporting no life in its own bosom at first, I believe to have been then, as now, most intimately and essentially connected, through the medium of the waters, with the life of the latter.

I shall begin by saying at once, and concisely, that my generalizations have led me inevitably to a novel conclusion, which will doubtless startle some; that LIFE was at the outset, has always been, and always must be, the governing *influence* in all chemical changes that have occurred and will occur, in the air, in the waters, and on the earth.

[It is not without a purpose that I here use the word *influence*. The words *force* and *power* I avoid, in laying down this principle, for reasons which I shall give at length on another occasion.]

In a previous paper I have put forth the proposition that at the Zoic Dawn the ocean must be believed to have been wholly in an oxygenated condition; that is, its constituents were at their maximum of oxidation. What then was the condition of the atmosphere corresponding to this? Before replying to this I must first propound another question, which involves an appeal to my fundamental doctrine of tracing back present changes to their beginnings. What, then, is our only known source of oxygen at present? Evidently the decomposition of carbonic acid by solar force, through the influence of plant-vitality; a never-ceasing agency which has continued to increase the proportion of oxygen and diminish that of carbonic acid in the air, since plants began to grow upon the earth, and has left its evidences on almost every leaf of the Book of Geological Ages.

Considering in connection with these facts the nature of oxygen, the greediness with which it enters into combination with other bodies, and applying the doctrine we started with, of following backward to their beginnings all such changes as we find in progress, I am led to lay down, as the primary postulate of a Zoic Theory of Chemical Geogony, the following: *the Prozoic Atmosphere contained very little or no free oxygen, probably none; but consisted essentially of carbonic acid, nitrogen and aqueous vapor.*

I anticipate, of course, a host of objections to so novel a view. One is that although plant-growth be independent thereof, yet germination requires free oxygen. Some may even maintain the assumption that plant-life must have commenced with germs.* To this speculative objection one answer is, why? Another answer, probably as speculative, however, as the objection itself; it is far from inconceivable, or even improbable that in a liquid medium containing such oxidating agents as the ferric compounds, the modification of eremacausis thought necessary to germination may have proceeded through the agency of these compounds.

Another objection may be that our present plant-life is accompanied by intermittent intervals of *absorption* of oxygen, during absence of the solar ray. But in any case the vegetative processes of the day we treat of, were in a measure independent of solar heat at least, if not of solar light also; of which the proof, even as late as the Carboniferous, is admitted. To the objection that in the earliest sediments we find little organic, or even carbonaceous matter, I reply that (apart from the graphites and sulphides, both believed organic in origin) it is easily understood that while life might withstand the ferric compounds, dead organic matter would quickly be burned up thereby, the sulphides having indeed resulted from this very burning process. I have applied the same principle to far later times, in a paper presented to the geological section, to explain the absence of fossils in the American Red Sandstones.

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*Those who will attach its due weight to the Mosaic Record in this regard, I may remind that the Creative Fiat called "the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself," etc. The question is an ancient one, "which was first, the hen or the egg?"

We here recognize another, and by no means a minor source of oxygen, namely, from the original oceanic metallic sulphates, which are now extant as sulphides, having given up their oxygen to the atmosphere by this indirect process of reduction by dead organic matter. I may add, in this place, that there has been still another, and a quite important source of oxygen, freed through vital influence; that O which represents the proportion deficient in bituminous coals to form HO with the H. This represents of course O which has at first been merely transferred from H to C, but as the CO^2, once formed, is again decomposed and its O set free, it amounts to the same thing.

Certain other objections to my views have been offered to me from time to time in conference and correspondence. With regard to my induction that the Ocean of the Zoic Dawn contained ferric constituents, it has been suggested that these would have been poisonous to life. This is but a question of degree, that is, of the strength of the solution. I claim only that the metals now present in the rocks as sulphides were present in the Prozoic Ocean as sulphates. The solution, in any case, could not have been a concentrated one. Moreover, the notion that ferric solutions are inimical to life, particularly in its lower forms, I think is unsupported by evidence. *Ferrous* solutions are so, without doubt, but not ferric. It has been claimed that subaerial action of carbonic acid, on alkalic and earthy silicates, would introduce into the ocean enough of bicarbonates to render it neutral, or even alkaline, and to precipitate all ferric oxides and hydrates. No doubt this took place *locally*, and the iron ore beds of these rocks are thus (and I believe thus only) to be accounted for. We have thus actually a new and substantial prop to my theory. Still this is a question of *time*, and to bring the whole of the vast ocean to a neutral or alkaline condition, must have required, as I am convinced, time enough for the deposition of the whole mass of the Eozoic schists, if not of a portion of the Palæozoic. I find that I have been misapprehended, in that I have been supposed to hold, in my paper on Gold Genesis, presented to this Association at Buffalo, in 1866, that gold has been deposited from the ocean equally in all geological ages. By my views, it cannot but be that the oldest sulphides were the most highly auriferous, at least of those (if any such there be still in existence) that have been deposited from the oceanic menstruum directly. It is *Gold Concentration*, and the formation of gold veins, that I claimed has occurred throughout all time, and is even now going on; and going on by virtue of the same agencies that I was the first to discover in 1858, the alternate formation, by oxidation, from auriferous pyrites, of ferric solutions of gold, and their reduction to ferrous conditions again, by farther reactions with unaltered pyrites or with organic matter.

My farther notes on this branch of my subject must be cut very short.

From the above it will be seen that my reasonings have led me to believe that, in Prozoic times, all the oxygen of the earth which now enters into the processes and changes going on upon its surface, all the *potential* oxygen of the earth (so to speak) was locked up in combined forms and divided between the earth's hydrosphere and its aerosphere; combined chiefly with iron in the former and with carbon in the latter.

I would next present the proposition that substantially all the potential *chlorine* was contained in the Prozoic, as it is in the present Ocean; as we know of no method by which chlorine (not probably oceanic) is now being introduced into the Ocean. As to *sulphur* and *phosphorus*, it is not certain that these two were *all* in solution in the original Ocean, as the fundamental rocky substratum or nucleus of the earth's crust being even at this time unrecognized, there is no certainty that it did not contain sulphides and phosphates before its subaerial erosion began. It is clear, however, that most of the sulphur, and probably of the phosphorus, of all sedimentary rocks was in the earliest Ocean, in acid forms. This Ocean then contained not less combined acids than ours.

With regard now to the metals of the Prozoic Ocean, or the bases with which its acids were combined; ferric and other oxides of the heavy metals, as I have shown, were among these, but never, of course, formed more than a minor percentage of the whole. One consideration is salient here, which is insisted on by **Sterry Hunt**, and scarce admits of a doubt, that the *characteristic* constituent of our Ocean, *sea-salt*, was originally present in far smaller proportion than now, and that it has been, at least in great part, a gradual product of the reaction of other preëxistent chlorides with the carbonate of soda that is continually carried in by rivers. It is thus that the carbonate of lime of sea shells is supplied. Carbonate of potash is also thus carried in, but the potash would appear to have been eliminated again in insoluble forms, such as *glauconite;* while we know no provision for removal of the soda. What were these preëxistent chlorides? Here is a point where, in our present condition of knowledge, there can be little but speculation; and where the great field for future investigation lies. There has already been discussion as to the questions whether *chloride of aluminum* was present or not (to the affirmative of which I incline): whether the amounts of the chlorides of *calcium* and magnesium, or either of them, were much greater formerly than now (of which I should incline to maintain the negative); which of the bases of the latter two chlorides predominated in the older Ocean, and so on. **Sterry Hunt** at one time made the suggestion that the waters of mineral springs from Silurian rocks, largely impregnated with these two chlorides, may be the fossil waters of the Silurian Ocean; but it seems probable rather that these are bitterns from the evaporations of enclosed portions of this Ocean. C. A. **Goessmann**, in a paper in the *American Journal of Science*, July, 1867, gives us a comparison between **Sterry Hunt**'s analysis of a salt spring* and his own of a Syracuse bittern, which has "practically ceased to evaporate" in the open air.

	(Goessmann).		(T. S. Hunt).
CaO, SO^3.	0.26		undet.
$CaCl$.	10.47		9.205
$MgCl$.	10.50		9.484
KCl.	3.38		
KBr.	0.45	$NaBr$.	undet.
$NaCl$.	8.75		17.400
Water.	66.19		
	100.00		

* Salt spring from near Bay of Quinte.

Goessmann argues that this resemblance shows the probability that such mineral waters "originate from mother-liquors or bitterns of the saline residue of marine evaporation of the Silurian age."

In the same paper, **Goessmann**, after referring to the views of **Karsten**, upon saline springs, as published by him in 1847, that these springs originate usually from rock-salt of Primitive (volcanic) origin, and are modified in composition by subsequent chemical action upon strata through which they effect their exudation; and that therefore the presence of chloride of calcium, with other compounds, was but accidental, says: that the presence of this chloride has since been recognized "as especially characteristic of the salt deposits of ante-tertiary dates. Consequently these have been considered as a product of the constant admixture of the oceanic waters of preceding geological periods; while on the other hand its absence in our present Ocean and in most salt deposits of a more recent date, is an established fact." He doubts not that the composition of the Ocean has changed and is now changing, yet he asserts "that our ideas concerning the main features of the Primitive or Silurian Oceans are still vague, and especially so upon this point" (*i. e.* the presence or absence of chloride of calcium).

In connection with these questions, it has occurred to me that **Ebelmen's** results (*Annales des Mines* [4], xii, 67) may have importance. He there shows that in the alteration and subaerial erosion of trap, five-sixths of the lime, while not more than one-third of the magnesia and but half the alkalies, are lost. It is to be remembered that in our present Ocean the total lime is but about one-third of the total magnesia.

Deferring for the present some views of my own upon these points, I shall close this chapter with a brief remark upon another important element entering into these great and complex problems.

To a superficial observer it might appear that, as the Ocean continually receives mineral matter in solution, and continually evaporates, it should become more and more charged with each of its dissolved constituents. This view, however, requires great modification, and here we find one of the grandest illustrations of the governing influence of Life, according to my proposition at the outset of this paper. For example, as stated above, the continuous predominance of magnesia over lime in our present Ocean, notwithstanding that rivers constantly pour in several times more of the latter than of the former. Through Zoic influence numerous other important constituents of the oceanic waters are eliminated and converted into permanently solid and insoluble forms, and thus constantly removed, in many cases quite as fast as they are supplied. Among these may be mentioned *carbonic acid*, *sulphur*, *phosphorus*, *potash*, *iron* and *silica*.

II. ZOIC HISTORY; FROM A CHEMICAL VIEW-POINT.

This chapter of the memoir relates to the demonstration, illustration, and general elucidation of my proposition of the ruling influence of LIFE in the Chemical History of Geological development. The subject is so vast that I have judged it proper not to make a vain attempt to condense it into a compass appropriate to the present occasion. DANA purposely omits this and its related subjects from his great work, on account of the "large amount of space" that would be required (DANA's Geology, p. 604).

I will but say that the general scope of my attempt is to show that a consistent theoretical scheme of Zoic development, including the *breaks* in Zoic history, and other readings of the geologic revelation, may be based on the study of the progressive (direct and indirect) influences of Life itself on the elements of the Earth, and on the forces that move and transform them. I claim that we have here an almost new and unexplored field of investigation, the working of which is to yield us results quite as positive, valuable, and wonderful as those of the study of fossils, and that the two studies will be found supplementary and altogether essential to each other. I start of course with my primary postulate, offered in the preceding chapter, that Life found the Earth in a condition of completed combustion, and that it has been the sole Oxygen-Maker, and Deoxidizer. Herein Life has done *no work*, it has but directed or governed the working forces of the Solar Emanation, in reversing the opposing influences of chemical affinity. It is a master, not a laborer. In my philosophy I regard neither vitality nor affinity as forces capable of transforming matter. They are both rulers of the forces that transform matter. Their reigns are antagonistic and alternating with each other. This is a subject which I propose to treat elsewhere.

In gradually impregnating the atmosphere with active oxygen, Life has profoundly altered, in an infinity of ways, the whole chemical status of the earth's crust, and, moreover, by substitution of oxygen for the preëxisting carbonic acid, the weight and density (though not the volume) and a multitude of other physical conditions of the atmosphere, have been changed.

As examples, I shall select, almost at random, one or two of the striking geological views which grow out of such chemical considerations. As to the mode of formation of *petroleum*, many speculations have been offered; but the following *fact* is here pointed out for the first time. The petroleum-bearing strata antecede the larger mass of the Carboniferous. It is clear, therefore, that the oxygen corresponding to the carbon, and part of the hydrogen, of the huge masses of coal of subsequent Carboniferous strata, as well as of the fossil matters since deposited (the Tertiary lignites for example) and of all now existing vegetation, had not then, as yet passed into the atmosphere. In an atmosphere so poor (comparatively) in oxygen, could decay and eremacausis proceed with the rapidity and intensity of our day? Would they not rather be necessarily so slow and imperfect that liquid products would be formed instead of gaseous? Of course the greater content of carbonic acid in the atmosphere during the days of Petroleum-Genesis (represented now by not only all the fossil matter, but by all the limestones, dolomites and chalybites since formed) may have contributed its modifying influence.

As another example of the intermitting sway of Life over the successive chemical conditions of the telluric surface, I introduce here what appears to me to be a new and prolific generalization relating to the oscillations of oxygen between carbon and iron in past ages. In addition to the former postulates of my Zoic Theory of Chemical Geogony, I may in fact here enounce another. In a previous paragragh, I have presented the induction: *In the Prozoic Era, all the Potential Oxygen of the Earth's surface was in combination, either with Iron in the Hydrosphere, or with Carbon in the Aerosphere.*

The new postulate I have to present is as follows:

A large part of the Potential Oxygen has been swinging like a pendulum, under the alternating impulses af Vitality and Affinity, between Iron and Carbon, since the Zoic Dawn.

The discussion of this Postulate would lead me too far on this occasion. To illustrate it I shall but present the following scheme, constructed in tabular form, to represent the influence of the principle upon the chemical state of the Iron-Oxides in the oceanic sediments of the successive geological days.

TABLE OF SECULAR GEOLOGICAL OXYGEN-OSCILLATIONS.

AGES.	DAYS.	GEN'L CONDITION OF IRON.
PROZOIC, ...	. . . .	*Ferric.*
EOZOIC, ...	. . . .	*Ferrous.*
LOWER SILURIAN, .	Potsdam, ...	*Ferric.*
	Calciferous, . . .	*Ferrous.*
	Trenton, ...	
	Hudson River, . .	
UPPER SILURIAN, .	Oneida, ...	*Ferric* (though marine); [Red Shales and Sandstones and Red Iron Ores].
	Medina, ...	
	Clinton, ...	
	Niagara, ...	
	Salina, ...	*Ferrous.*
	Lower Helderberg,	
DEVONIAN, ...	Oriskany, ...	*Ferric* (?)
	Upper Helderberg,	*Ferrous.*
	Hamilton, ...	
	Chemung, ...	
	Catskill, ...	*Ferric* (for 6000 feet).
CARBONIFEROUS, . .	. . . .	*Ferrous.*
PERMIAN, ...	. . . .	*Ferric.*
	. . . .	
MESOZOIC, ...	Triassic, ...	
	Jurassic, ...	*Ferrous.*
	Cretaceous, . . .	
CENOZOIC, ...	Tertiary, ...	*Ferric.*
	Anthropozoic, . .	

III. CHEMICAL REVELATION OF A FINAL ZOIC CATASTROPHE.

In the course of the above attempts to fathom the Chemistry of the Past, indications have become apparent to me, which are applicable to the Future: and which seem to be of truly vital interest to the human race. There are chemical changes now active on the Earth's surface, easily demonstrated, whose continuance must inevitably bring about the final extinction of man, and ultimately of all other life upon our planet.

A single one, among the most important and inevitable of these, I propose here to explain.

What furnishes the actual fundamental chemical nutriment or pabulum, of vital existence? No chemist will contradict, when I say that it is the carbonic acid of the atmosphere. How long is this going to last? This question many will regard as absurd, having been taught that it is restored at least as fast as (possibly at the present day faster than) it is consumed. The notion, stereotyped in the text-books, is that, whatever may have been in the past, an equilibrium has been reached during the age of man, between production and consumption. This cannot be, unless there can be shown a mode of restoration corresponding, and equivalent to, each mode of consumption. There is one such mode, however, still active and continuous, and without sign of cessation, which will ultimately exhaust the atmosphere of its carbonic acid, and thus put an end to organic life. This agency is itself due and has ever been due to vital influences. It seems part of the great law of Zoic development that Life slowly evolves the causes of its own ultimate extinction on the Earth. The agency I refer to is that by which marine animals with calcareous shells or skeletons secrete carbonates from the ocean water, the carbonic acid of these carbonates having been originally derived from the atmosphere. Such carbonic acid thus passes into solid forms, permanent and for ever unavailable thereafter. This is where the great machine runs down, and Affinity obtains its final victory over its mysterious antagonist Vitality.

Whenever the last molecule of carbonic acid produced from the combustion of all the carbon on the Earth shall have been locked up in this shape, no form of life now known to us can any longer be possible, and the present Zoic Cycle must end. Comparatively and geologically speaking, the end is near; though millions of years may yet intervene. But long before this end of *all* life, the atmosphere must gradually diminish in its capacity to produce food suitable for man. No human power that we can discern can avert this result. Man, by burning up the carbon stored in eras past in the Earth's *viscera*, is doing his utmost to preserve the status of the machine, possibly even partially and temporarily *rewinding* it (here is a curious topic for speculation); but it must still continuously run down. In the oceanic depths, this precious constituent of the air, in which we literally, in a higher than poetic sense, "live, and move and have our being," is continually undergoing

> "A sea-change
> Into something rich and strange,"

never to reappear in form available to life, until indeed that time shall arrive, when "the elements shall melt with fervent heat;" and when, under the influence of this heat, the calcic and magnesic carbonates shall be converted into igneous silicates, rendering up again the treasures of carbonic acid in their marble grasp; the atmospheric oxygen—representative of Affinity, enemy of Vitality—shall also then be at least partially withdrawn by oxidation of sulphides and of ferrous oxide; and the Earth be thus far advanced in preparation for a new Zoic Cycle.

8. NOTICE OF SOME NEW TERTIARY AND CRETACEOUS FISHES.

By O. C. MARSH, of New Haven, Conn.

(ABSTRACT.)

THE fossils exhibited by Professor Marsh, and briefly described in this communication, consisted of the remains of several new species of fossil fishes from the Cretaceous and Tertiary formations of the United States, and nearly all were from the greensand of New Jersey.

Among the remains of Tertiary fishes were specimens indicating two very diminutive species of Sword-fish, each of which was represented by the beak, or united premaxillaries. One of these fossils, for which the specific name *Histiophorus parvulus* was proposed, was a nearly perfect "sword," only about three inches long; which would indicate that the entire fish was probably not more than twenty inches in length. The beak in this species is slender and very pointed. It is compressed transversely, but has the lower surface nearly flat. The brush-like teeth on this portion are reduced to two narrow bands. The remaining surface of the sword is irregularly striated. This interesting specimen was found in the Eocene greensand of Monmouth County, New Jersey, at the pits of the Squankum Marl Company, and was presented to the Museum of Yale College, by O. B. Kinne, Esq.

The second small species of Sword-fish apparently belongs to a new type, allied to the extinct *Cœlorhynchus* of the Eocene. The beak resembles in general form that of *Cœlorhynchus*, but is much smaller, tapers more rapidly, and has the inferior surface flattened, and marked by two shallow grooves. Like the rostrum of that genus it has a double cavity at the base, and a single one through the main portion of the shaft. The upper surface is also fluted, but much more delicately than in any known species of *Cœlorhynchus*. When entire the beak was apparently not more than two and a half inches in length, and the whole fish probably did not exceed fifteen inches, which is by far the smallest sword-fish known. For the extinct genus represented by this specimen, the name *Embalorhynchus* was proposed, and the species was called *Embalorhynchus Kinnei*, after the discoverer, O. B. Kinne, Esq., whose explorations in the Tertiary of New Jersey have brought to light many interesting fossils. This specimen, also, was found in the Eocene greensand, at the pits of Squankum Marl Company.

A new species of *Phyllodus*, the first discovered in this country, was likewise announced, and briefly described under the name *Phyllodus elegans*. It was represented by a pharyngeal, dental plate, with the teeth in an excellent state of preservation. This specimen differs from the corresponding part in the known species of this genus, in its form, which is subtriangular, and especially in its much smaller size, as it is but nine and a half lines in length, or scarcely more than one-fourth as large as the smallest already described. In the number and position of the various teeth it appears to most nearly resemble *Phyllodus toliapicus* Ag. (Poissons fossiles, Vol. II, pl. 69 *a*, fig. 1) from the London clay, but differs from that species in having the central teeth proportionally much more elongated and the lateral ones less numerous. This unique specimen was found in the Eocene greensand at Farmingdale, New Jersey, in the pits of the Squankum and Freehold Marl Company, and was presented to the Yale Museum, by Major A. J. Smith, the Superintendent.

A second and larger species, apparently of the same genus, was represented by the central portion of the corresponding dental plate. It is readily distinguished from all the described species of *Phyllodus*, by the unusual thickness of the teeth, and by the fact that the longest of the series are considerably curved, so that the crushing surface of the plate is concave transversely. This species was named *Phyllodus curvidens*. The specimen on which it is established was found near Shiloh, Cumberland County, New Jersey, in the Miocene Marl, and is, therefore, the most recent known representative of this type of fishes.

Another new species from the Tertiary was indicated by the palatal plate of a fossil ray, for which the name *Myliobates bisulcus* was proposed. It differs from the species of this genus already described, in having the central row of teeth marked along the median line by a deep groove. In other respects the dental surface is remarkably smooth and flat. This specimen is from the Eocene greensand of Monmouth County, New Jersey, and also belongs to the Museum of Yale College.

Among the Cretaceous specimens exhibited were several ichthyodorulites, which evidently belonged to Chimæroid fishes, and indicated a species new to science. One of these was a dorsal spine, nearly perfect, and about fourteen inches in length. It is somewhat curved, and remarkably slender, being but nine lines in antero-posterior diameter at the base, and tapering regularly to the apex. It is compressed transversely, suboval in general outline, and has the posterior surface slightly concave in the lower portion. The upper half of this surface is armed with two rows of very sharp, decurved teeth, while the corresponding part of the anterior face has a sharp cutting edge, which toward the distal end is finely serrated. The sides of the spine are smooth, or faintly striated. This specimen was found by John G. Meirs, Esq., in the upper Cretaceous marl bed, near Hornerstown, New Jersey, and the species is named *Dipristis Meirsii*, in honor of the discoverer. Fragments of this species, of much larger size than the specimen described, are not uncommon in the same geological horizon in other parts of the State.

Another Cretaceous species, *Enchodus semistriatus*, was described from a number of shed teeth. The most perfect of these was fourteen lines in length and three and a half lines in diameter at the base. It was slightly sigmoid in shape, compressed, and has in front a sharp cutting edge which is minutely denticulated. The rounded posterior surface was marked by delicate striæ, except near the apex, which is furnished with a distinct barb. Some of the smaller teeth were more nearly straight, and apparently without the barb. All the specimens of this species yet discovered are from the lower Cretaceous Marl bed of New Jersey.

II. ZOOLOGY.

1. OBSERVATIONS ON PHYLLOPOD CRUSTACEA OF THE FAMILY BRANCHIPIDÆ, WITH DESCRIPTIONS OF SOME NEW GENERA AND SPECIES, FROM AMERICA.* By A. E. VERRILL, of New Haven, Conn.

Addison Emery

THE Phyllopod Crustacea are among the most interesting of the Entomostraca, as they are also by far the most beautiful. In size the species generally exceed those of most other groups, except the Limuloids and Cirripeds. The numerous peculiar natatory appendages, which are moved with a peculiarly graceful undulatory motion, give them an elegant appearance when in motion. In this country they have hitherto been but little

* An abstract of this communication was printed in the "American Journal of Science," xlviii, p. 244, Sept., 1869, and reprinted in "The Annals and Magazine of Natural History." In the present paper many alterations and additions have been made.

studied, and doubtless many more forms remain to be discovered.

Among those already described from North America, are two species of *Apus*, *A. glacialis*, from the Arctic regions, and *A. longicaudatus* Leconte, from the Rocky Mountains.

In the following remarks those belonging to the Branchipidæ are alone considered.

ARTEMIA Leach, 1819.

This genus is characterized by having eleven pair of four-jointed branchial "feet" or fins along the sides of the body, the middle ones being longest; each joint bearing flat branchial appendages, ciliated by sharp setæ, as in the other genera of the family. The abdomen is slender, six-jointed, the last joint long, terminated by two small projecting appendages, each bearing six to ten plumose setæ. The first abdominal segment bears the external sexual organs of the male, and a short, dilated, ovigerous pouch in the female. In the male the head bears in front a pair of large, three-jointed hooks or clasping organs, each of which has on the inner side of its basal joint a small, rounded appendage; a pair of slender antennæ, just back of these, terminated by two or three minute setæ; a pair of pedunculated compound eyes, and a dark spot on the middle of the head, which is the remains of the single eye of the young. The mouth below is provided with a broad labrum, a pair of mandibles, two pairs of jaws, and a pair of lateral papillæ. In the female the head lacks the stout claspers, which are replaced by a pair of comparatively small, simple, horn-shaped organs.

According to Dr. Baird,* the genus *Eulimene* Latreille, 1817, was based on specimens of *A. salina*, which were badly preserved and erroneously described. That name was, however, preoccupied among Acalephs.

This interesting genus is remarkable for its habit of living and flourishing best in very saline and alkaline waters, such as the natural salt lakes of Egypt, Utah, etc., and the artificial brines formed by the evaporation of sea-water by exposure to the heat of the sun, as in England, France and the West Indies.

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*Monograph of the Family Branchipodidæ, etc., in Annals and Mag. Nat. History, vol. 14, p. 216, 1854.

The species first made known, *A. salina* Leach (*Cancer salinus* Linn.), was first described by Schlosser,[*] who found it in great profusion in the brines of Lymington, England. Linné indicates it also from the salt lakes of Siberia (perhaps a distinct species,[†] and probably the same as that observed by Pallas[‡] in great numbers in the Great Schimélée). More recently it has been described from the salterns of southern France, at Montpellier, etc.[§] The genus has been found also in the Lakes Goumphidich, Amaruh and Bédah in Egypt, which are reported to be both very saline and alkaline, their bottoms being "covered with a layer of crystals of carbonate of soda, sulphate of soda, and common salt," while the density of the water is stated at 1.255. The Egyptian species appears not to have been described as yet.[||] In the Antilles *A. Guildingi* Thompson occurs.[¶] *A. Milhausenii* Edw. (Fischer sp.) is found in Lake Loak in the Crimea.[**] A few years ago Prof. B. Silliman presented to the Museum of Yale College a number of specimens of a new species, *A. Monica* V., which he collected in Mono Lake, California, where it occurs in great abundance associated with the larvæ of *Ephydra*.[*] The water of this lake is very dense, and not only very saline, but also so alkaline that it is said to be used for removing grease from clothing. I have been unable, however, to find any reliable analysis of this water. It is said to contain, also, biborate of soda. Prof. Silliman informs me that the genus also occurs in Little Salt Lake. It occurs in great abundance in Great Salt Lake, Utah, as I am informed by Prof. D. C. Eaton, who obtained specimens there during the present summer.[†] The water of Great Salt Lake has usually been described by travellers as destitute of all life, but according to Prof. Eaton it contains not only an abundance of *Artemiæ*, but also various other small animals, insect larvæ, etc. The density of the water is stated at 1.170°, but doubtless varies according to the season.[‡] It yields, according to Dr. Gale, over 22 per cent of solid matter,[§] while the Syracuse Saline, one of the richest natural brines in the United States, contains but 19.16 per cent.[‖] A few weeks ago Mr. Oscar Harger discovered another new species, *A. gracilis* V., near New Haven, under very peculiar circumstances. On the long wooden bridge across West River and the extensive salt marsh on the West Haven side, are placed large wooden tubs filled with water from various pools on the marsh, to be used in case of fire. By long exposure to the sun and air the water in these becomes concentrated and thus furnishes suitable stations for the rapid increase of *Artemiæ*. On examining the tubs the first of August I found eight of them partly filled with water, in six of which the

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[*] Observations périodiques sur la physique, l'histoire naturelle et les beaux-arts, par Gautier, 1756 (with figures). An extract from this is republished in Annals des Sciences nat., 2e ser., t. 13, p. 226, 1840, in an elaborate description of the anatomy, development, habits, etc., of *Artemia salina* by M. Joly, illustrated by two excellent plates of the female and young. M. Joly failed to observe the male among more than a thousand females, and therefore doubted whether the sexes were distinct, suggesting that the males, very well described by Schlosser, were only the young, although that author described them as clasping the females in the well known manner, but he did not observe the actual copulation.

See also an article by Thomas Rackett, in Trans. Linn. Soc. of London, vol. xi, p. 205, pl. 14, 1812 (figures very bad); Thompson, Zoological Researches, No. 5, p. 105, t. 1 and 2; W. Baird, Nat. Hist. of the British Entomostraca, p. 61, tab. ii, figs. 2-4 (figures very good, but the specimens probably not full-grown).

[†] *Polyartemia forcipata* Fischer, is from the rivers of Siberia and also from Lapland. It resembles *Artemia*, but has nineteen pairs of natatory appendages and also peculiar appendages to the male claspers, with the second joint divided.

[‡] Voyage en différentes provinces de l'empire de Russie, t. ii, p. 505 (t. Joly).

[§] M. Payen, Note sur des animaux qui colorent en rouge les marais salans, Ann. des Sci. nat., 2e ser., t. 6, 1836, p. 219 (contains experiments on the effects caused by altering composition and density of the water); also op. cit., t. 10, 1838, p. 315; Joly, op. cit., t. 13, p. 225, 1840 (see above); Milne Edwards, Crustacés, t. iii, p. 369, 1840.

[||] Audouin, Ann. des Sci. nat., 2e ser., t. 6, 1836, p. 230.

[¶] Thompson, Zool. Researches, fas. 7, pl. I, figs. 11-12.

[**] Edwards, Crustacés, t. iii, p. 370, 1840.

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[*] Verrill, Proceedings Boston Soc. Nat. Hist., vol. xi, p. 3, 1866 (the larvæ were wrongly referred to *Eristalis*); Packard, on Insects inhabiting salt-water, Proc. Essex Inst., vol. vi, p. 41, 1869.

[†] This species has since been examined and found to be a distinct species, *A. fertilis*.

[‡] The density of the water of the Atlantic Ocean is stated at 1.026; that of the Dead Sea 1.130 to 1.227.

[§] This solid matter, according to Dr. Gale (Amer. Journal Science, II, vol. xvii, p. 129), has the following composition:

Chlorid of sodium,	20.196
Sulphate of soda,	1.834
Chlorid of magnesium,	.252
Chlorid of calcium,	trace
	22.282

[‖] For analyses of several of these brines, see Dana's System of Mineralogy, 5th edition, 1868, p. 118.

Artemiæ were found in abundance, though more numerous in one than in any of the others. In one tub, in which the water had a decidedly milky appearance, they were so abundant that hundreds could be obtained in a few minutes. The water in some of the other tubs containing them was of a reddish or brownish hue, or about the color of weak tea. In two no Artemiæ could be seen, and in these the water appeared to have been more recently renewed. Search was made in the pools from which the water had been taken, but no *Artemiæ* were found, though doubtless from these places the progenitors of those inhabiting the tubs must have been taken. It is probable that in the pools they exist in very small numbers, being kept in check partly by various small fishes and other enemies, and partly by the unfavorable character of the water, while in the tubs the density of the water is more favorable for their rapid increase, and unfavorable or fatal to their enemies.* The water from the tubs, when examined with a high power of the microscope, was found to be filled with immense numbers of infusoria of various kinds, such as monads, vibrios and bacteria, most of which were so small as to be distinguishable only as moving points with a $\frac{1}{6}$ inch objective.

In the salterns of France the *Artemiæ* are associated with immense numbers of a monad, usually bright red in color, which has been named *Monas Dunalii* by Joly, who attributes to it the red color which the brine assumes just before crystalization,† as well as the red color observed in the *Artemiæ*, which doubtless feed upon it, as well as upon various other living infusoria, and dead animal and vegetable matter of various kinds.‡ The *Monas Dunalii* appears in abundance in the water having the density most favorable for *Artemia*, but increases in far greater proportion in the still denser, nearly or quite saturated brine in which *Artemia* does not live. The observations of Payen and Joly show that the *A. salina* of

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* The density of the water in two of the tubs containing most *Artemiæ*, was 1.065, equivalent to a brine containing 9.07 per cent of salt. One of those tested was brownish, the other milky.

† Recherches sur la Coloration en rouge des Marais Salans Méditerranéens, par M. Joly, Annals des Sciences naturelles, 2e ser., t. xiii, 1840, p. 266.

‡ According to M. Joly, op. cit., p. 262, a beetle, *Hydroporus salinus* Joly, also inhabits the salterns, where the water has a density of 6° or 7° Baumé, and preys upon the *Artemiæ*.

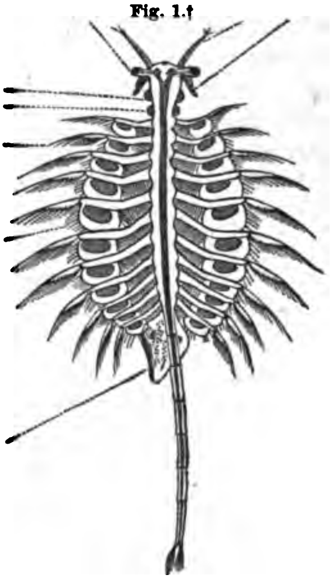
France can exist in waters varying in density from 4° to 20° Baumé, but that they flourish best in those that have a density of 10° to 15°.* According to Rackett those of Lymington do not live in the water which is undergoing the first stage of concentration, but only in the pans of concentrated brine, containing about "a quarter of a pound of salt to the pint."

Our *A. gracilis* can exist without apparent inconvenience when the water in which they occur is diluted with an equal bulk of fresh water, as well as when it is much concentrated by evaporation. The water in which they were found varies in density from 1.060 to 1.065.

ARTEMIA GRACILIS Verrill.

American Journal of Science, xlviii, p. 248, September, 1869; reprinted in Ann. and Mag. of Nat. History, Vol. iv, p. 331, 1869.

Fig. 1.†



Body slender, in the male about .3 of an inch long; in the female .4. Claspers of the male relatively long and powerful, first joint thickened, with a distinct angle at the articulation on the outside and a short, rounded, nearly semicircular process on the inside near the base, about its own diameter from the base; second joint broad, flattened, continuous with the third joint, strongly curved, outline nearly regularly convex on the outside, until near the middle it suddenly bends inward forming an obtuse angle, beyond which the outline is concave to the last articulation, where it becomes again convex, forming on the last joint a slight, rounded angle, the inner edge is nearly straight, or but slightly concave, to the last articulation, where there is a slight but distinct angle; last joint triangular, longer than broad, tapering to the acute, slightly excurved point. Antennæ slender, elongated, reaching beyond the first articulation of the claspers, terminal setæ minute. Abdomen slender, smooth, the terminal lobes small, longer than broad, broadly rounded at the end, slightly constricted at the base inside, each bearing usually 7 or 9 plumose setæ, the central ones much the longest. Ovigerous pouch of the female, when seen from below, flask-shaped, the neck extending backward and downward, short, thick, subcylindrical toward the end, the body of the "flask" short, thick, swollen laterally, broader than long, the sides terminating outwardly in a small, triangular, sharp tooth, sometimes showing a minute spine. This pouch is generally filled with numerous large, brownish eggs.

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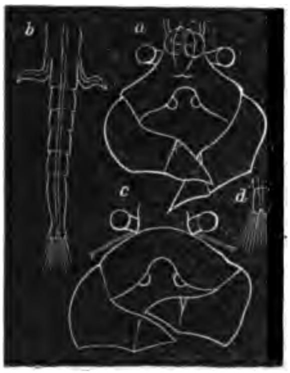
* 4° to 20° Baumé is equivalent to a density of about 1.02 to 1.16; 10° to 15° = 1.075 to 1.117. A brine having a density of 1.020, which is nearly that of sea-water, contains about 2.766 per cent of salt; one of 1.160 contains 21.219 per cent; one of 1.075 about 10.279 per cent; 1.117 about 15.794 per cent.

† Figure 1.—*Artemia gracilis*, female, enlarged; drawn from living specimen by J. H. Emerton.

Fig. 2.*



Color generally reddish, flesh-color, or light greenish, translucent; the males usually lighter, greenish white, the intestines generally showing through as a dark reddish or greenish median line; eyes very dark brown, or black; ovaries often whitish, along each side of the abdomen.

An adult male gives the following measurements:—distance between eyes 1.81^{mm}; breadth of head .76; length of eye-stalks .62; length of first joint of the claspers .91; its breadth .72; breadth of its appendage .18; length of second and third joints from outer edge of first articulation to the tip 2.48; greatest breadth .87; breadth at last articulation .72; length of last joint 1.05; length of last joint of abdomen, exclusive of appendages, 1.00; its breadth .31; length of prece-

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*Figure 2.—*a*, head of *A. gracilis*, male, viewed from below, showing part of the mouth organs, the eyes and the claspers; *b*, abdomen of the same, with male organs; *c*, head of *A. Monica*, showing eyes, antennæ and claspers; *d*, caudal appendages of the same. All these figures are from camera-lucida drawings by the author, and enlarged seven diameters.

ding joint .42; its breadth .37; length of terminal appendages .21; breadth .096; length of longest setæ .70.

New Haven, Conn. Charlestown, Mass., on railroad bridge across Charles River in tubs of concentrated sea-water.*

ARTEMIA MONICA Verrill, op. cit., p. 249.
Figure 2, *c. d.*

Form similar to that of the preceding species, but a little larger and stouter. The largest female is 13^{mm} (.52 of an inch) long, the abdomen being 6^{mm}; and 5^{mm} across the branchial feet in their natural, partly extended, position. The largest male is 11.5^{mm} (.45 of an inch) long, the abdomen being 6^{mm}. The claspers of the male are relatively stouter, the hook or outer two joints being much broader, more triangular, and less elongated. The inner edge of the first joint, as seen from below, is regularly convex, bearing the appendage on its most convex part, and not so near the base as in *A. gracilis*, the distance being about twice the breadth of the organ, which is about as broad as long and regularly rounded. At the articulation the outer edge of the joint projects as a distinct angle. The second and third joint together have a nearly triangular form, the breadth being about half the length; the outer edge is regularly rounded, shorter than in the preceding; it forms little more than a right angle with the front edge, which is nearly straight or a little concave, sometimes slightly convex at the last articulation, but not forming a distinct angle there; the inner edge of the hook is a little concave on the first joint, becoming convex at the last articulation, where there is a distinct but very obtuse angle. The last joint is almost regularly triangular, about as broad as long, tapering to an obtuse point, the inner edge being a little convex. The antennæ are very slender and do not reach the first articulation of the claspers. The caudal appendages are smaller than in *A. gracilis*, and scarcely longer than broad, rounded at the end, terminated by nine or ten very slender pulmose setæ. The egg-pouch of the female is broad flask-shaped, strongly convex in the middle below, the sides not forming such sharp angles as in *A. gracilis*.

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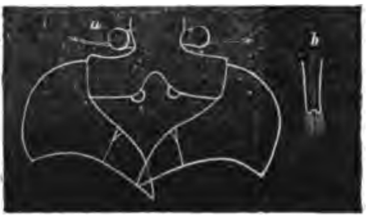
*During the progress of the meeting Dr. G. H. Perkins discovered this species in great abundance in tubs of water taken from the Charles River and kept on the Eastern Railroad bridge. Professor Agassiz also stated that he had formerly observed this or a similar species in the salt vats at Cape Cod.

The English specimens of *A. salina*, as figured by Baird, differ from both the preceding species in having longer, more curved, and sharper clasping hooks, and the basal appendage more elongated; the egg-pouch, though badly figured, is of a very different form. The French specimens, as figured by Joly, appear like a distinct species, the egg-pouch being of a very different form, and the caudal appendages very much longer and larger than in either of our species, while Baird's figure represents them as very small; but his specimens appear to have been smaller, and may have been immature, for these species begin to breed before they are half-grown. Whether the French species be distinct from the English can only be determined by additional examinations, especially of the male, for the male of the former appears not to have been figured hitherto.

ARTEMIA FERTILIS Verrill.

American Journal of Science, Vol. xlviii, p. 480, Nov., 1869.

Fig. 3.[*]



This species grows to a larger size than I have observed in either of the others, some of the specimens being full .75 of an inch long. The claspers of the male (fig. 3, *a*) are stout, with the second joint broader and more triangular than in either of the preceding species. The outer angle of the second joint of the claspers is very prominent, and the outline from thence to the tip is decidedly concave, in this respect resembling those of *A. gracilis* more than those of *A. Monica*. The caudal appendages (fig. 3, *b*) appear to be shorter than in either of the others, but this character varies considerably with age in all the species of this genus.[†] Great Salt Lake, Utah,—Sereno Watson; D. C. Eaton; S. A. Briggs.

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[*] Figure 3.—*a*, head of *Artemia fertilis* V., male; *b*, caudal appendages. Camera-lucida drawings by the author from alcoholic specimens, enlarged seven diameters.

[†] For this reason several nominal European species, established mainly on differences in the caudal lobes and setæ, are probably only the young of others, or all perhaps of *A. salina*, especially since those with small caudal lobes and few or no setæ, are described as small; as for example, *A. Milhausenii*, *A. arietina* and *A. Koppeniana* (Fischer species).

Another species has recently been made known from New South Wales, *A. proxima* King, Entom. Soc., N. S. Wales, Vol. i, pl. xi.

This species occurs in vast numbers in the very dense waters of Great Salt Lake, together with the larvæ of *Ephydra*.

BRANCHIPUS Shœffer.

Branchipus Shœffer, Elementa entomologica, Pl. 29, figs. 6, 7, 1766, (type, *B. pisciformis* = *B. stagnalis* Linn. sp.).

Branchipus (*pars*) Lamarck, Latreille, Leach, Edwards.

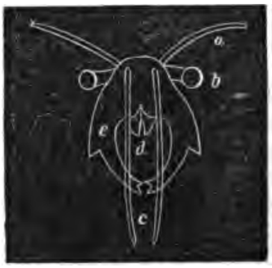
Chirocephalus (*pars*) Dana (*non* Bénédict Prévost, 1803; Jurine, Thompson, Baird).

Under the name, *Branchipus*, at least five or six generic groups have been confounded by various authors.

Branchipus should be restricted to the original species described by Shœffer and the allied species, of which *B. stagnalis* (Linn. sp.) is one, if not identical with *B. pisciformis*, as is generally supposed.

As thus restricted the genus is characterized by the stout two-jointed claspers of the male, with or without a tooth near the base of the hook, the basal joint being swollen; by having a pair of simple appendages resembling antennæ between the bases of the claspers in front (fig. 4, *c*); by the large, thick, oval egg-pouches of the female, and, apparently, by the structure of the branchial organs. The typical species have, in addition to the pair of slender antenniform organs, a short bilobed organ (*d*) between the bases of the claspers in front.

Fig. 4.*



The type of this genus is *B. stagnalis* of Europe (fig. 4, head of male). It is doubtful whether any other described species can be properly referred to the genus.

STREPTOCEPHALUS Baird.

Monograph of the Family Branchipodidæ, etc., in Annals and Mag. Nat. History, vol 14, p. 219, 1854.

Heterobranchipus Verrill, American Jour. Science, xlviii, p. 250, 1869.

Body and caudal appendages as in *Branchipus;* natatory organs in eleven pairs. The claspers of the male are long, three-jointed, tortuous or twisted; the terminal joint subdivided more or less, into two or more branches, or bearing slender appendages. Near base of claspers are two antenniform organs. Front of head with a bilobed organ, between bases of claspers. Male organs long, slender, complex. Egg-pouch elongated or conical.

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* Figure 4. — *Branchipus stagnalis* Latreille, head of male, enlarged; *a*, antennæ; *b*, eyes; *c*, antenniform organs; *d*, bilobed organ at base of claspers; *e*, claspers. From Latreille after Shœffer's figure of *B. pisciformis*.

This genus includes *S. cafer* (Loven sp.) Baird, from the marshes of South Africa; *S. similis* Baird, from St. Domingo, West Indies; *S. torvicornis* (Waga sp.) Baird, from near Warsaw, in the latter the claspers are said to be as long as all the rest of the body; *S. rubricaudatus* (Klunzinger sp.) from Kosseir, near the Red Sea.* The last species has very long slender claspers in the male; the first joint bearing a slender antenniform organ at its outer end; the second with three slender teeth-like processes on the outer side; the third is crooked, subdivided at the end into two long crooked branches, of which the inner is much the longest, sickle-shaped, and serrated on the inner edge. The external male organs are comparatively small and simple. The egg-pouch is long, slender, and beaked at the end. This and *S. torvicornis* are closely allied and should be considered typical species of *Streptocephalus*, while *S. cafer* and *S. similis* might well be separated, as a subgenus, at least, under the name of *Heterobranchipus*.

CHIROCEPHALUS Prevost, 1803.

This genus, established for *C. diaphanus*, is evidently very distinct from both the preceding. The typical species is large, stout, and remarkable for the singular appendages between the claspers of the male, on the front of the head. These consist of two long, ligulate, fleshy processes, serrated on each side, which coil in a spiral beneath the head, but when extended, as in copulation, reaching beyond the claspers; attached to the outer side of each of these are four long processes, strongly serrate on the inner edge, and near the base another large, broad, thin, subtriangular appendage, its edges strongly serrate, especially in front, capable of folding up like a fan when not in use. The claspers have a much swollen basal joint, a strongly serrate tooth on the inside of the base of the second joint, which beyond this is slender and regularly curved. Egg-pouch long-oval, large and thick; caudal appendages large; male organs and branchiæ peculiar.

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* Zeitschrift für Wissensch. Zoologie, xvii p. 23, Taf. iv. figs. 1–9, 1867.

C. diaphanus Prev., inhabits fresh-water pools in France, Switzerland and England. It is well described and figured in Baird's British Entomostraca, p. 39, tab. III and IV.

Dr. Baird, in his monograph, refers to this genus the following species: —

C. claviger (Fischer, sp.), from Siberia; *C. birostratus* (Fischer. sp.), near Charkow, Russia; *C. lacunæ* (Guérin, sp.), near Fontainebleau; *C. Middendorffianus* (Fischer, sp.), from Siberia and Lapland.

The last appears, however, to belong rather to our *Branchinecta*, and *C. lacunæ* ought, perhaps, to form the type of a distinct genus, since it lacks the complicated appendages of *C. diaphanus*. This reference of *C. birostratus* is also scarcely satisfactory; it may be nearer to our *Eubranchipus*.

EUBRANCHIPUS, gen. nov.

Body robust, with eleven pair of natatory appendages. Male with large head and very stout claspers; first joint of clasper much swollen, capable of retracting the basal portion of the second joint into their cavity; second joint stout at base; in the typical species with a large tooth on the inside, the outer portion tapering, rather obtuse.

Front of head, between the bases of the claspers, bears two thin, flat, tapering appendages, serrated on the edges and transversely striated or jointed. Caudal appendages long lanceolate, with numerous plumose setæ. Egg-pouch short and thick, swollen and broad-oval.

Besides the following species this genus appears to include *Branchipus spinosus* Edw., from a salt lake near Odessa, but the latter appears to have no tooth at the base of the second joint of the claspers.

EUBRANCHIPUS VERNALIS Verrill.

Branchipus vernalis Verrill, op. cit., p. 251.

Form rather stout, large; the full grown females are 23^{mm}

(.90 of an inch) long, the abdomen being 14^{mm}; and 6.5^{mm} wide across the branchial organs in their natural position; breadth of head across the eyes 4^{mm}. A large male is 22^{mm} (.86 of an inch) long, the body 12^{mm}; the breadth of head across eyes 5^{mm}; the entire length of claspers 8^{mm}. The claspers are very large and strong, the basal joint much swollen with a soft integument, capable of retracting the basal portion of the second joint into itself by involution of its outer edge; the second joint is elongated, broad and stout at base, with an angle on the outside, from which it rapidly narrows by strongly concave outlines on each edge, but most so on the outside; at the constricted portion, not far from the base, it bears a large, strong, very prominent, crooked, bluntly pointed tooth, which is directed inward and backward, not serrate on its outer side; beyond the tooth the rest of the joint is long and rather slender, curved outward and forward at base, having just beyond the tooth on the inside a distinct but very obtuse rounded angle, from which the outline slightly curves inward to near the tip, which is a little dilated and recurved. The basal portion, including the tooth, is retracted into the first joint in some

Fig. 5.*

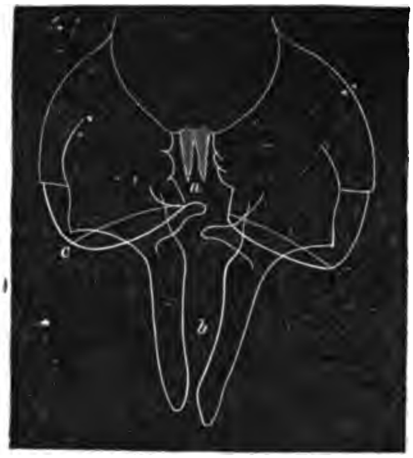

Fig. 6.†

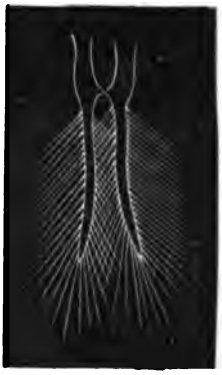

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*Figure 5.—Head of *Eubranchipus vernalis*, male; *a*, serrated organs between the bases of the claspers; *b*, second joint of claspers; *c*, first joint, with the basal portion of the second joint somewhat retracted into its cavity.

†Figure 6.—Caudal appendages of the same specimen. Both figures are from camera-lucida figures by the author, enlarged six diameters.

specimens. On the front of the head between the basal joints of the claspers are two flat, lanceolate, short, ligulate, fleshy processes, with finely serrate edges, usually coiled down, but when extended scarcely more than half as long as the basal joint of the claspers. Antennæ small and very slender, tapering, reaching a little beyond the eyes. Caudal appendages long, rather narrow, slightly swollen at base, gradually tapering to the acute tips, and bearing along the sides, except at base, very numerous, long plumose setæ. Egg-pouches short, broad-oval, nearly as wide as long, slightly three-lobed posteriorly, the central lobe largest, sides extended and largely adherent to the sides of the abdomen, length 4^{mm}; breadth 3.5. Body flesh-color or pale red, the intestine darker red or greenish.

A large male gives the following measurements: length of first joint of claspers 4.62^{mm}; diameter 2.40; length of second joint 4.14; breadth at base 1.90; at tooth .72; in middle .52; length of tooth .90; its diameter .33; length of caudal appendages 4; breadth at base .33; in middle .20; length of setæ 2; length of antennæ 3.

New Haven, in stagnant pools,—J. D. Dana, D. C. Eaton, A. E. Verrill; Salem, Mass., April 19, 1859,—R. H. Wheatland, C. Cooke (from Essex Institute); Cambridge, Mass.,—A. E. Verrill.

This differs widely from all the described species of Europe, in the character of the claspers of the male and their appendages. *E. spinosa* resembles our species somewhat in the frontal appendages between the claspers, but lacks the conspicuous tooth at the base of their second joint. The shape of the egg-pouch in our species is also characteristic.

This is doubtless the species referred to by Dr. Gould under the name of *Branchipus stagnalis.** Dekay† copied the diagnosis of *B. stagnalis* (?) from a foreign work, and gave a figure of *Chirocephalus diaphanus*, copied apparently from Desmarets, pl. 56, which is itself a copy.

This species appears very early in spring, often in great numbers, in quiet pools. I have never seen it later than the middle of May, yet since the individuals seen in early spring are full-grown, it might, doubtless, be found also in autumn.

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* Invertebrata of Massachusetts, p. 339.

† Natural History of New York, Zoology, Part I, Crustacea, p. 63, pl. ix, fig. 36.

BRANCHINECTA Verrill, op. cit., p. 250.

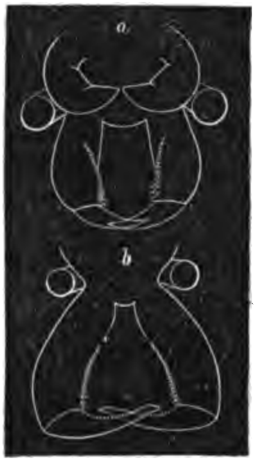
Form rather slender, with the median appendages longest, so as to somewhat resemble *Artemia* in outline, but larger. Male with rather slender, pointed, rounded, two-jointed claspers; the basal joint somewhat enlarged, with an oblique row of small teeth on the inner side; the second joint curved, tapering, the inner edge usually finely serrulate. Front of head and base of claspers without other appendages of any kind. Caudal appendages slender, or narrow lanceolate, fringed with plumose setæ. Egg-pouch much elongated, and in some, if not all species, with lateral lobes at base.

BRANCHINECTA ARCTICA Verrill.

Branchipus (Branchinecta) arcticus Verrill, op. cit., p. 253, 1869.

Branchipus paludosus Packard, Invertebrate Fauna of Labrabor, in Mem. Boston Soc. Natural History, i, p. 295 (*non* Müller).

Fig. 7.*



Form slender; body short; abdomen elongated. A full sized male is 20^{mm} (.80 of an inch) long, exclusive of the claspers, the abdomen being 13^{mm}; the breadth between the eyes 3^{mm}. A female 20^{mm} long, with the abdomen 12^{mm}, has an egg-pouch 6.2 long. Branchial "feet" slender, elongated, the middle ones longest, 4 to 5^{mm} long when extended. Claspers of the male (fig. 7*a*) rather long and slender; the basal joint is but little swollen, elongated, regularly curved, with a small tooth or prominent angle at the articulation on the inside, and on the inner side a row of numerous small, distinct, sharp teeth, extending from the articulation about half way to the base, and arranged somewhat obliquely; second joint slender,

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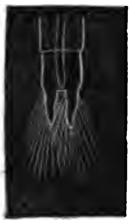
*Figure 7.—*a*, head of *B. arctica*, male, showing the jaws, eyes and claspers; *b*, same of *B. Grœnlandica*, except that the jaws are omitted.

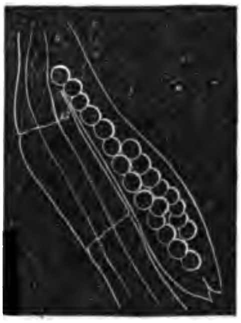
regularly curved, tapering to a blunt point, the inner edge minutely serrulate. Front simply curved with no appendages. Antennæ slender, scarcely more than half the length of the basal joint of the claspers. Labrum long and narrow, mandibles stout, strongly curved, bluntly pointed. Caudal appendages (fig. 8) slender lanceolate, rather small, with long slender setæ. Egg-pouch (fig. 9) much elongated, slender, subcylindrical, beaked or slightly bilobed at the end, the upper or dorsal lobe longest; basal portion with two small rounded lateral lobes.

Fig. 8.*



A large male gives the following measurements: breadth between outer extremity of eyes 3.46$^{\mathrm{mm}}$; diameter of eyes .66; length of basal joint of claspers 1.66; breadth .71; length of second joint 1.29; breadth at its base .46; width of mandibles at middle .66; length of caudal appendages .96; breadth at base .16; length of longest setæ .84 to 1$^{\mathrm{mm}}$.

Fig. 9.†



Color of preserved specimens pale reddish, with dark green intestine. Labrador, at "Indian Tickle" on the north shore of Invuctoke Inlet, abundant in a pool of fresh-water. — Dr. A. S. Packard.

Dr. W. Baird in Ann. and Mag. Nat. Hist., vol. 14, 1854, p. 228, mentions imperfect specimens of a species brought from Cape Krusenstern by Sir John Richardson, which were probably of the present species. It was found with *Apus glacialis*.

BRANCHINECTA GRŒNLANDICA Verrill.

Branchipus (*Branchinecta*) *Grœnlandicus* Verrill, op. cit., p. 253.

A little stouter than the last; the largest male is 17$^{\mathrm{mm}}$ long exclusive of claspers, the abdomen being 10$^{\mathrm{mm}}$, including caudal appendages. Claspers similar to those of *B. arctica* but more elongated, the basal joint less curved, and the second joint longer, less regularly curved, tapering more quickly at base and consequently more attenuated beyond the middle and with more slender tips, which are nearly straight. The tooth on the inside of the first joint is rather more prominent, but the row of teeth along the inside is similar. Caudal appendages stouter, tapering more rapidly. External male organs slender, curved outward, swollen at base. The largest female is not mature and the egg-pouch contains no eggs; it is small, slender, elongated, subcylindrical, beaked at the end.

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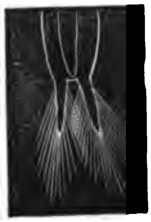
* Figure 8. — Caudal appendages of *B. arctica*, male.

† Figure 9. — Egg-pouch of *C. arctica*, containing eggs. All these figures are from camera-lucida drawings by the author, enlarged seven diameters.

Fig. 10.*



The largest male gives the following measurement: breadth between eyes 3.20^{mm}; length of basal joint of claspers 2.81; breadth .95; length of second joint 2.24; its breadth at base .76; length of caudal appendages .86; width at base .24; Length of setæ .76.

Greenland.—Dr. Chr. Lütken (from the University Zoölogical Museum, Copenhagen).

Of this species I have seen but four specimens, which were sent to Dr. A. S. Packard by Dr. Lütken, under the name of *B. paludosus* Müller. The latter appears to be quite distinct, judging from the figures; it is represented as having very slender, linear, caudal appendages. In the form of the egg-pouch, and the serration of the first joint of the claspers it is similar.

This species is very closely allied to *B. arctica*, and when a larger series of specimens can be examined it may prove to be only a local variety, but the specimens studied show differences that seems to warrant their separation.

Branchinecta paludosa (*Branchipus paludosus* Müll.) is also a northern species of this genus, allied to the two preceding, but differing from both, according to the figures and descriptions, as mentioned under the last. *B. ferox* (*Branchipus ferox* Edw., Crust., iii, p. 369) is from fresh-water near Odessa. The description is so brief and imperfect that its generic affini-

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*Figure 10.—Caudal appendages of *Branchinecta Grœnlandica* V., male, enlarged seven diameters.

ties cannot be made out with perfect certainty, but it agrees better with this genus than with any other. *B. Middendorffana* (Fischer sp.) from Siberia and Lapland, may also belong here.

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2. On the Trend of the Rocky Mountain Range North of Lat. 60° and its Influence on Faunal Distribution. By W. H. Dall of Washington, D. C.

About latitude 60° north, this great range nearly approaches the coast range, and about latitude 64° bends, in a confused mass of mountains, trending with the coast to the south and westward, and gradually coalescing and becoming merged with the Alaskan Range, which forms the backbone of the peninsula of Aliaska.

To the north of this there are no considerable elevations worthy of the name of mountains, except a few peaks of the Romanzoff Mountains. All the ranges of hills and mountains have the same general trend.

Bering Strait is only thirty fathoms deep, and although there is a deep ocean valley culminating in the mouth of Plover Bay to the westward of the strait, yet an elevation of one hundred and eighty feet would unite Asia and America with a dry plateau offering no obstacles to the migrations of animals and plants.

The old maps all represent the Rocky Mountains as extending to the shores of the Arctic Ocean, but this is incorrect.

The effect of this bend of that chain is to have a high broken plateau to the northward, by which the eastern birds, &c., pass to the shores of Bering Sea, while the characteristic west coast fauna is almost entirely excluded, though we have birds hitherto known from Europe, Siberia and Polynesia, breeding at the Yukon mouth with *Ampelis garrulus*, *Colaptes auratus* and other eastern birds, while the eastern pike (*Esox estor*) reaches to tide water in the Yukon. In fact the whole fauna has strongly marked Canadian characteristics, which are lost when we pass south of the Alaskan Range.

III. BOTANY.

1. THE ROCKY MOUNTAIN ALPINE REGION. By C. C. PARRY, of Washington, D. C.

THE wooded belt of coniferous trees that, with irregular local interruptions, clothes the Rocky Mountain slopes, commences by a somewhat scattering growth near their base, at an average elevation of six thousand feet above the sea. This belt acquires its densest growth, and exhibits the greatest number of distinct species, between seven thousand and nine thousand feet elevation, and terminates by an abrupt well marked line at an average height of eleven thousand three hundred feet.

These plainly recognized features are readily explained by reference to the corresponding climatic conditions here exhibited. Thus the growth is most dense and varied where the exposures present a suitable condensing surface, and where there is the greatest and most regular amount of aqueous precipitation, caused by a mingling of the cool descending currents of air from the higher elevations meeting the warm ascending currents charged with moisture from the heated plains below; at this irregular point of junction summer rains and dews are frequent, and the conditions for arborescent growth are most favorable. At still higher elevations the actual limit of tree growth is determined by conditions of temperature, which satisfactorily explain the peculiar features of vegetation here met with.

Most noticable of these is the singular abruptness, by which this limit of upright tree growth is here marked. You are struggling through a tangled maze of fallen timber and dense underbrush, overshadowed by tall trees, with spreading roots bedded in a saturated spongy soil, when suddenly, without any sensible dwarfing of intermediate forms, you come upon open spaces, where stunted trees fantastically gnarled and twisted, with depressed flattened summits, offer little obstruction to the open view above. Through these obstructions, stepping on the very tops of matted trees which a few rods below rear their pointed spires to a height of thirty to forty feet, you come upon the bare alpine slopes, which continue with variously interrupted rocky exposures to the dividing ridge two thousand to twenty-five hundred feet higher.

In the absence of any continuous meteorological observations at or above the timber line, the most satisfactory explanation of the peculiar features here presented is this: The so-called timber line marks the extreme point of *minimum* winter temperature below which no exposed phenogamous vegetation can exist. All that survives above this point does so by submitting to a winter burial of snow, beneath which protecting cover it is enabled to maintain its torpid existence. The early autumnal fall of snow commences in the latter part of September and receives constant additions through the fall and winter months, during which it retains its light feathery texture, and is not sensibly wasted by melting till the clear lengthening days of early summer dissolve them rapidly, giving origin to the dashing streams that pour down the upper valleys.

It is the pressure of this accumulating weight of snow that gives the fantastic shape to the tree vegetation, that struggles for existence above the well marked timber line, and we can readily note instances, here and there, where from some peculiar condition of wind, or a limited amount of winter-snow in particular seasons, points and patches of dwarfed tree growth being left unprotected, have been blasted and destroyed. Otherwise we can observe still more frequently where ambitious upper branches projecting into the sunlight of this Arctic winter, have been nipped and killed. In these unmistakable signs of the struggle for vegetable existence are also exhibited some of the most peculiar and marked features of the Alpine scenery. This dwarfed tree growth, persisting above the timber line, is as we might naturally suppose confined to sheltered valleys, or on the lea-side of abrupt rocks, where the drifted snow lies heaviest. The point of greatest snow accumulation is mainly determined by the shelter afforded along the upper line of the timber growth, at which locations the snow drifting from the bare spaces above is lodged, hence early in the thawing season, these locations offer the principle obstructions to travel, presenting treacherous fields of snow, often overarching rushing torrents; here also the vegetation is longest delayed, and is comparatively meagre. It is on the more open exposures above that the alpine flora offers its greatest variety, and most attractive features, and through a brief flowering period, extending from June to September, presents a succession of forms and colors, attractive to the eye of a naturalist, and such as is nowhere else so comprehensively exhibited. As these alpine plants owe their existence to the protection afforded by winter snow, they naturally include a number of species that also flourish at lower elevations. Thus in the accompanying list of alpine plants, out of *one hundred and forty-two* species, I note fifty-six as exclusively confined to the alpine exposures. The usual characters of alpine plants here, as elsewhere exhibited, consist in a dwarfed habit of growth, late period of flowering and early seeding, the forms being almost exclusively perennial.

Of Phenogamous plants persisting to the highest elevations, reaching to fourteen thousand feet and upwards, we may enumerate the following: *Thlaspi cochleariforme*, *Claytonia megarrhiza*, *Trifolium nanum*, *Oxytropis arctica*, *Saxifraga serpyllifolia*, *Androsace chamæjasme*, *Chionophila Jamesii*, *Eritrichium aretioides*, *Polemonium confertum*, *Gentiana frigida*, *Salix reticulata*, *Lloydia serotina*, *Luzula spicata*, *Carex incurva*, *Poa arctica*.

Of the thirty-four natural orders represented in the alpine flora, thirty-one belong to *Phenogamous* plants, the remaining three include the higher orders of *Cryptogams*, of the latter, Ferns are represented by a single species, not exclusively alpine (*Cryptogramme acrostichoides* R. Br.). Mosses are more numerously represented, but are still comparatively rare, while Lichens are most abundant and afford the greatest number of species.

Of the Phenogamous orders twenty-seven belong to *Dicotyledons*, four to *Monocotyledons*. Of these the natural order, *Compositæ*, comprises the largest number of species, viz.: twenty-four included in thirteen genera; *Ranunculaceæ* has five genera, seven species; *Cruciferæ*, five genera, six species; *Caryophyllaceæ*, five genera, six species; *Leguminoseæ*, two genera, four species; *Rosaceæ*, four genera, five species; *Saxifragaceæ*, two genera, nine species; *Primulaceæ*, two genera, four species; *Scrofulariaceæ*, six genera, ten species; *Gentianaceæ*, two genera, six species; *Salicaceæ*, one genus, four species; *Conifereæ*, three genera, five species; *Juncaceæ*, two genera, seven species; *Cyperaceæ*, one genus, four species; *Gramineæ*, five genera, nine species. Of large families entirely unrepresented, we may note *Solanaceæ*, *Labiateæ*.

The superficial extent of these bare alpine exposures can only be approximately estimated in the absence of any exact topographical measurements. Taking the main mountain mass extending through Colorado Territory, or between 37°, and 41°, north latitude, including the high offsets and detached peaks, rising above eleven thousand feet, it would be safe to allow an average width of five miles, for the entire distance, in a straight line, representing in round numbers an area of from twelve hundred to fifteen hundred square miles. Throughout this extent there is great uniformity in the vegetation presented, though agreeably varied by the different exposures or conditions of soil and moisture. Wherever the peculiar texture of the underlying rock has favored disintegration, and the accumulation of soil, a rich alpine sward is presented, made up of densely matted grasses, carices, and plants adapted to pasturage. Here the mountain sheep, the elk, and the Rocky Mountain goat, graze during the summer months, and the mountain ptermigan, and dusky grouse feed and rear their young. When once made accessible it will, no doubt, afford a favorite resort for summer pasturage, and may eventually yield choice dairy products equalling those of the Swiss Alps, or produce delicate fibrous tissues, rivalling those of the looms of Cashmere.

As a sanitary retreat during the summer months it is unexcelled in the purity and coolness of its atmosphere, the clearness of its flowing streams, and its picturesque extended views. There are no elevated points that cannot be safely ascended, and dangers from snow avalanches, or land slips, are so rare as not to be taken into consideration. Of the high culminating points met with in the district under review, including Long's peak on the north, and the Sierra Blanca on the south, there is a remarkable uniformity in the average elevation; all as far as accurately measured rising above fourteen thousand feet. Gray's peak in the dividing ridge, which is now a point of common summer resort, so far carries the palm in an elevation of fourteen thousand two hundred and fifty-one feet. Its associate peak (which it is most earnestly hoped may bear the appropriate name first proposed, of *Torrey's peak*, in commemoration of the early botanical labors of our veteran American botanist) is thought to be somewhat higher, an interesting point which will no doubt be determined by Professor Whitney in his present summer's exploration of that region.

In the accompanying list of alpine plants, published some years since in the Transactions of the St. Louis Academy of Science, I confine the term "alpine" to such plants as are met with on the bald exposures above the timber line; by a (*) prefixed I would indicate those species which are exclusively confined to such localities, while others not thus marked, are also met with at lower elevations.

The subjoined localities, whenever given, denote that the species referred to, is not peculiar to the Rocky Mountains, but is also met with in the different regions there named. *Eu.* indicating Europe, and *As.* Asia.

The concluding summary embodies the general results of my observations in the Rocky Mountain alpine district.

ROCKY MOUNTAIN ALPINE PLANTS.

Ranunculaceæ.—Anemone narcissiflora, L. *Eu. As.;* A. Nuttalliana, D.C.; Ranunculus Eschscholtzii, Schlecht, Greenland; *R. adoneus, Gray; Trollius laxus, Salisb. *Eu.;* Caltha leptosepala, D.C.; Aquilegia brevistyla, Hook.

Cruciferæ.—Cardamine cordifolia, Gray; Erysimum pumilum, Nutt; *Draba crassifolia, Graham; D. alpina, L. *Eu.;* *Smelowskia calycina, C. A. Meyer, *As.;* Thlaspi cochleariforme, D.C. *As.*

Papaveracæ.—*Papaver alpinum, L. *Eu. As.*

Violaceæ.—Viola biflora, L. *Eu. As.*

Caryophyllaceæ.—Lychnis apetala, L. *Eu. As.;* *Silene acaulis, L. *Eu. As.;* *Paronychia pulvinata, Gray; *Arenaria arctica, Stev.; A. Fendleri, Gray; Cerastium vulgatum, var. Behringianum, Gray.

Portulacaceæ.—* Claytonia megarrhiza, Parry; C. Virginica, L. var.; * Talinum pygmæum, Gray.

Leguminoseæ.—Trifolium dasyphyllum, Torr. & Gr.; * T. nanum, Torr.; * T. Parryi, Gray; * Oxytropis arctica, R. Br.

Rosaceæ.—Sibbaldia procumbens, L. *Eu. As.;* * Dryas octopetala, L. *Eu. As.;* * Geum Rossii, Ser. *As.*; Potentilla fastigiata, Nutt.; * P. nivea, L. *As.*

Onagraceæ.—Epilobium alpinum, L. *Eu.*

Grosulariaceæ.—Ribes lacustre, Poir. var. (R. setosum, Dougl.).

Crasulaceæ.—Sedum rhodanthum, Gray; S. Rhodiola, L. *Eu. As.*

Saxifragaceæ.—Saxifraga nivalis, L. *Eu.;* * S. cernua, L. *Eu. As;* S. controversa, Sternb. *Eu.;* *S. debilis, Engel.; * S. serpyllifolia, Ph.; * S. flagellaris, Willd. *As.*; S. punctata, L. *Eu. As.;* Parnassia fimbriata, Banks; P. parviflora, D.C.

Umbelliferæ.—* Cymopterus alpinus, Gray; Archangelica Gmelini, DC. *As.*

Araliaceæ.—Adoxa moschatellina, L. *Eu. As.*

Compositæ.—* Erigeron uniflorum, L. *Eu. As.;* E. grandiflorum, Hook; Aster glacialis, Nutt.; A. salsuginosus, Richards. *As.;* Solidago virgaurea, L. *Eu. As.;* * Aplopappus pygmæus, Gray; * A. Lyallii, Gray; * Actinella grandiflora, Torr. & Gr.; A. acaulis, Nutt. var.; Chænactis achilleæfolia, Hook & Arn.; Artemesia arctica, Less. *As.;* * A. scopulorum, Gray; Antennaria alpina, Gaertn. *Eu.;* Senecio amplectens, Gray; S. triangularis, Hook; * S. Soldanella, Gray; S. Fremontii, Torr. & Gr.; S. integerrimus, Nutt.; Arnica angustifolia, Vohl. *As.;* A. mollis, Hook; A. latifolia, Bongard; * Cirsium eriocephalum, Gray; Troximon glaucum, var. dasycephalum, Torr. & Gr.; Macrorhynchus troximoides, Torr. & Gr.

Campanulaceæ.—* Campanula uniflora, L. *Eu. As.;* C. rotundifolia, L. *Eu. As.*

Ericaceæ.—Vaccinium myrtillus, L., var. *As.;* V. cæspitosum, Michx. *As.*

Plantaginaceæ.—Plantago eriopoda, Torr.

Primulaceæ.—* Androsace chamæjasme, L. *Eu. As.;* A. septentrionalis, L. *Eu.;* * Primula augustifolia, Torr; P. Parryi, Gray.

Scrophulariaceæ.—Pentstemon glaucus, Graham; * P. Harbourii, Gray; * Chionophila Jamesii, Benth.; Mimulus luteus, L. var. alpinus; * Synthyris alpina, Gray; * Castilleia breviflora, Gray; C. pallida, Kunth. var.; * Pedicularis Parryi, Gray; * P. Sudetica, Willd. *Eu. As.;* P. Grœndlandica, Retz.

Boraginaceæ.—* Eritrichium aretioides, D.C. *As.;* Mertensia alpina, Don.; M. Sibirica, Don. *As.*

Hydrophyllaceæ.—Phacelia sericea, Jacq.

Polemoniaceæ.—Polemonium pulchellum, Bunge. *As.;* * P. confertum, Gray; * Phlox Hoodii, Richardson; Gilia congesta, Hook.

Gentianaceæ.—Gentiana acuta, Michx.; * G. barbellata, Engel; G. prostrata, Hænk. *Eu. As.*; * G. frigida, Hænk.; *Eu. As.;* G. Parryi, Engel.; Swertia perennis, L. *Eu. As.*

Polygonaceæ.—Polygonum bistorta, L. *Eu. As.;* P. viviparum, L. *Eu. As.;* Oxyria digyna, R. Br. *Eu. As.;* Eriogonum flavum, Nutt.

Salicaceæ.—* Salix reticulata, L. *Eu. As.;* * S. glauca, L. *Eu. As.;* S. arctica, R. Br. *Eu. As.;* S. discolor, Willd. *Eu. As.*

Coniferæ.—Abies Engelmanni, Parry; A. grandis, Lindl.; Pinus aristata, Engl.; P. flexilis, James; Juniperus communis, L. *Eu. As.*

Liliaceæ.—Zygadenus glaucus, Nutt. *As.;* * Lloydia serotina, Reich. *Eu. As.*

Juncaceæ—* Luzula spicata, D.C. *Eu. As.;* L. parviflora, DC. *Eu. As.;* Juncus Drumondii, Meyer; * Juncus Hallii, Engel.; * J. Parryi, Engel; * Juncus triglumis, L. *Eu. As.;* * J. castaneus, Sm. *Eu. As.*

Cyperaceæ.—Carex atrata, L. *Eu. As.;* C. rigida, Good.; * C. incurva, Lightf. *Eu.;* * C. filifolia, Nutt.

Gramineæ.—Phleum alpinum, L. *Eu. As.;* * Poa Andina, Nutt.; P. alpina, L. *Eu. As.;* * P. arctica, R. Br.; P. nemoralis, L. *Eu. As.;* Aira cæspitosa, L., var. arctica, Thurb. *Eu.;* Festuca rubra, L. *Eu. As.;* F. ovina, L. *Eu. As.;* Triticum strigosum, Less. *As.*

Filices.—Cryptogramme acrostichoides, R. Br.

SUMMARY.

1. The persistent bodies of snow which, in variable amount at different seasons, are ordinarily met with on the higher elevations of the Rocky Mountains, do not indicate a region above the true snow line, but result from the accumulation of drifted snow, filling up recesses and sheltered depressions to such an extent that the summer sun is not sufficient to melt the deeper portions, which thus remain from year to year, varying in amount according to the quantity of fallen snow, or the character of the succeeding summer season as to its snow-melting power.

2. Hence, we have no constant accumulation of snow forming what is known in the European Alps as *Nèvé*, the pressure of which from the higher elevations gives origin to glaciers.

3. In the absence of glaciers and heavy snow accumulations on mountain slopes, we do not encounter the usual glacier phenomena so often referred to in the European Alps, and only meet occasionally with avalanches due to accidental local causes.

4. The winter snows being of the light character pertaining to the higher regions of the atmosphere, and not subject to condensation by alternate thawing and freezing during the season of their occurrence, are thus peculiarly liable to the transporting movements of the prevailing winds. Hence results an accumulation of snow in the upper valleys, by which these frozen treasures of winter are safely stored away, to be dispensed in fertilizing streams to the lower valleys during the dry warm season, when most required for agricultural or mining purposes.

5. The peculiar alpine vegetation, attaining to elevations of fourteen thousand feet above the sea level, is enabled to maintain its existence by the protection afforded by the ordinary winter snows, and, in the more sheltered and deeply covered valleys, includes plants which flourish also at much lower elevations.

6. The true timber line, everywhere exhibited as a well masked horizontal plane, varying in elevation, according to the degree of latitude or character of exposure, from ten

thousand seven hundred feet to twelve thousand feet above the sea, indicates a limit beyond which the minimum winter temperature is destructive of all exposed phænogamous vegetation, and whatever in the form of tree growth persists above this point, can only do so by being deeply buried in the accumulation of winter snow, which weighing down their branches, gives that distorted growth pecular to such localities.

7. In the accompanying list, comprising one hundred and forty-two species of alpine plants, fifty-six are noted as exclusively alpine, or confined to the bald alpine exposures; eighty-four species, as far as at present known, are peculiar to the Rocky Mountain range, or to Northern America, while the remaining fifty-eight species are common to the European or Asiatic Alps, or to high northern latitudes of both continents.

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2. On the Sexes of the Plants. By Thomas Meehan of Germantown, Penn.

In my paper on "Adnation in Coniferæ," read before you last year, I believe I established the fact that the stronger and more vigorous the axial or stem growth, the greater was the cohesion of the leaves with the stem. By following the same line of observation, I have discovered some facts which seem to me to afford strong probability that similar laws of vigor or vitality, govern the production of sexes in plants.

If we examine Norway spruces when they are in blossom in the spring, we find the male flowers are only borne on the weakest shoots. The female flowers, which ultimately become cones, appear only on the most vigorous branches. As the trees grow, these strong shoots become weaker by the growth of others above shading them, or by the diversion of food to other channels, and gradually as these shoots become weaker, we find them regularly losing the power of producing female flowers. The law in this instance seems very clear, *that with a weakened vitality comes an increased power to bear male flowers*, and that *only under the highest conditions of vegetative vigor* *are female flowers produced.* The arbor-vitæ, the juniper, the pine, in fact all the different genera of coniferæ that I have been able to examine, exhibit the same phenomena, but the larch will afford a particularly interesting illustration. When the shoots of the larch have a vigorous elongating power, the leaves. cohere with the stem, only foliaceous awns give the appearance of leaves. But when they lack vigor—lose the power of axial elongation—true leaves, without awns, appear in verticils, at the base of what with more vigor, might have been a shoot. Every one is familiar with these clusters of true leaves on the larch. In the matter of sex an examination of the tree will show the following grades of vigor. First a very vigorous growth on towards maturity, or the age necessary to commence the reproductive processes. The reproductive age is less vigorous. Taking a branch about to bear flowers we find somewhat vigorous side branches, with the usual foliaceous awns. The next year we find some of the buds along these side branches again branch, but the evidently weaker buds, make only spurs with leaf verticils. As these processes go on year after year, the verticils become shaded by the new growths, and get weaker in consequence, and thus in the third year some of the strongest of these verticils commence to bear female flowers, or a few of the weaker male ones. But only in the fourth or fifth year, when vitality in the spur is nearly exhausted do male flowers abundantly appear. The production of male flowers is the expiring effort of life in these larch spurs. They bear male flowers and die.

What is true of Coniferæ seems also to exist in all Monœcious plants. In the *Amentaceœ* the male flowers appear with the first expansion of the leaf buds in spring, as if they were partly formed during the last flickerings of vegetative force the fall before—but a vigorous growth is necessary before the female flowers appear. In *Corylus*, *Carpinus*, *Quercus*, *Juglans*, *Alnus*, and I believe all the common forms of this tribe, we find the female flowers only on the strongest young growths, and only at or near the apex of the first great wave of spring growth, as if it were the culmination of a great vegetative effort which produced them instead of the decline as in the male. Some of these plants have several distinct waves of growth a year, each successively decreasing in vigor. In such cases the female flowers appear at the apex of the first and strongest wave, and not on the apex of the shoot. This beautiful illustration of the connection of vigor and the sexes can be seen particularly in some oaks, and in *Pinus pungens*, *P. mitis*, *P. rigida* and *P. inops*. In the larch and white spruce a second wave will often cause a spur to elongate, late in the growing season, and even cause a shoot to push from the apex of the young cone. It is essential to note these varying waves of vigor, in one season's growth, and that the apex is not always the strongest point. In *Cyperaceæ*, particularly, these waves vary, and thus we find sometimes the male, sometimes the female flowers at the apex of the culm, but always the female in the line of greatest vigor. I do not know of any case where the sexes are separate on the same plant, that extra vigor does not accompany the female, and an evidently weakened vitality the male parts.

Mere vigor, however, though it often indicates healthy vitality, does not always, or alone do so. *Pinus Mugho* seldom attains ten feet high, and its shoots are not near as vigorous as its near relative *Pinus sylvestris*, yet it commences its bearing age by a free and vigorous production of female flowers. But power of endurance is a test of strong vitality, and an alpine form should possess this in a high degree. In its relation to sex this form of vitality — endurance — will also have an interest. The vitality of a tree is always more or less injured by transplanting. Sometimes it is so injured that leaves never push again, and it always pushes out later than if it had not been moved, and just in proportion to the injury to vitality is the lateness of pushing. Clearly, then, comparative earliness of leafing, is a test of vigorous vitality. Now some Norway spruces push forth earlier than others. There is as much as two weeks difference between them, and it is remarkable that those which push out the earliest — may we not say those which have been most favored by the vital force — are the most productive of female blossoms. Arboriculturists may make good use of this fact. Norway spruces which have a drooping habit, are the heaviest cone bearing forms. No way has hitherto been discovered to detect them until they get to a bearing age. Now it will be seen that the earliest leafers will be the chief cone bearers or weeping trees.

It is not so easy to see the influence of vigor or other forms of high vitality, as affecting the sexes in hermaphrodite as in Monœcious plants, yet here also are some remarkable facts of a similar character. In some flowers the forces which govern the male and female portions respectively, seem nearly equally balanced. Then we have a perfect hermaphrodite — one with the stamens and pistils perfect, each part communicating its influence to the other — a self-fertilizing flower. In many species, however, we notice a tendency to break up this balance. It becomes pistillate or staminate, by the greater development of one force or the other. If the force is in the female direction, it begins by requiring the pollen from some other flower to fertilize itself — if in the male direction, the number of stamens or petals is increased, or the one metamorphosed into the other. The interest for us in this sexual question is to note that just in proportion as the sexes diverge in this manner, in just the same proportion does vigor or some other form of strong vitality accompany the female in the one case, and weakness the male in the other. For instance in the male direction, when the stamens have been turned into petals, or the number of petals increased, growth is never so strong, and life is more endangered. Double camellias, roses, peaches, and other things, have to be grafted on single ones in order to get them to be more vigorous growing plants, and every florist knows how difficult it is to get roots from a double flowered cutting than a single one. Sometimes the male principle, which loves to exhibit itself in the gay coloring of the petals, seems to influence the leaves, and they become colored or variegated, and then also a weakened vitality follows. Variegated box, variegated Euonymus — no variegated plant will grow as freely, endure summer's heat or winter's cold so well, as its regular green leaved form. On the other hand, when the balance goes over in the female direction, we see it characterized by greater vigor than before. It has long been noted that pistillate varieties of strawberries are more prolific than the hermaphrodites, though this is modified according to the disposition of the variety to produce runners, which are really but a form of viviparous flower branches, and thus a legitimate part of the female system. So in *Viola*, where we have many forms of female influence, from the underground stolon, or the creeping runner which propagates without impregnation, to the apetelous flower which mature seeds on the smallest possible quantity of pollen, up to the perfectly formed hermaphrodite flower of spring — all regular and gradual grades of one identical female principle; in contrast with species, which throughout maintain a near connection with the male principle by retaining pure hemaphrodite flowers through their whole stage, we find those possessed of the highest types of vitality which are evidently the most under the laws of female influence.

In a brief paper like this it is not my purpose to introduce more of the facts I have observed than will sustain the probability of the theory I have advanced. I do not wish to urge it for adoption — my object is to excite investigation on the part of other observers, who will, I think, find everywhere about them, that wherever the reproductive forces are at all in operation, it is *the highest types of vitality only which take on the female form.*

I have confined myself to sex in plants, botany being my special study. Do the same laws prevail in the Animal World? I think they do, but this being out of my favorite province, I dare not discuss it, but content myself with the bare suggestion.

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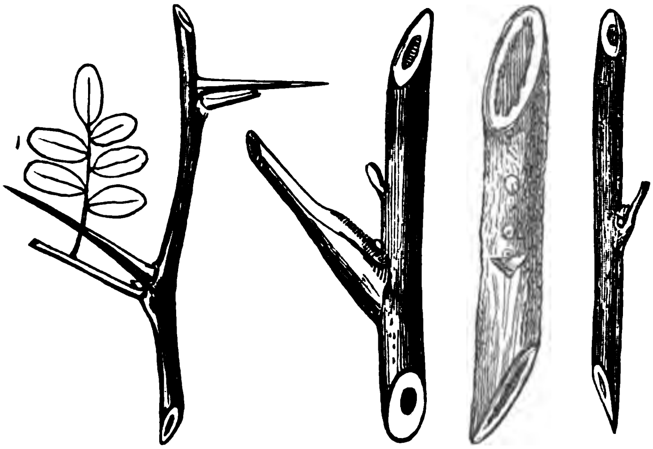
3. ON THE GLANDS OF CASSIA AND ACACIA. By THOMAS MEEHAN, of Germantown, Penn.

DR. ASA GRAY, in his *Manual of Botany*, describes the glands of *Cassia marilandica*, as being towards the base of the petiole. This is true only of the upper leaves. The lower ones have the glands varying in position from near the base up to the lowest pair of Pinnæ. It is clear, from this varying position of the gland, that it is not a normal part of the individual leaf structure. If it were, it would be always in the same position relatively with other parts. It is fair to assume that it is locally an accident. An examination of two allies, *Gleditschia* and *Gymnocladus*, will afford the clue to its real nature.

Of course all know that the spine in *Gleditschia* is an abortive or stunted shoot, and that the true shoot springs when it grows at all, from the bud below. There are therefore two axial buds in this plant, the one above the other. I have discovered that a similar system of buds exist in *Gymnocladus*, only that there are often three in one line, one above another, instead of only two as in *Gleditschia*. These buds rarely push forth into shoots, and hence as you know its name *Gymnocladus* has been given to it from its naked main branches. It is now worthy of note that the upper bud, the one farthest removed from the axil, is the largest and best developed; and that when a shoot does come it proceeds from it. Also that one or two of the lowest buds are very often below the centre of the axis of the petiole. Turning now to *Gleditschia*, we find that in its two buds, it is the lowest, or what in the other case would be the weakest, which in this instance makes the shoot. It is the upper bud which makes the spine, and I suppose has the least developed vitality. Thus we see in these two allied plants there is no fixed system in the order of axial development; sometimes it is the upper bud, sometimes the



Gleditschia triacanthos. **Juglans cinerea.** **Gymnocladus canadensis.** **Itea Virginica.**

lower, which first pushes into growth. We also see by the failure of the upper bud in *Gleditschia* to elongate — by its degradation, to a mere spine — that there is a tendency in all these axial parts to become assimilated into each other.

Turning now to *Cassia Marilandica* and *Acacia julibrissin*, we find that their normal system is to have two buds, one above another, as in the other two; and that the lower bud is nearly opposite the centre of the leaf petiole as before mentioned in *Gymnocladus*; and further that in its early attempts at development it has been absorbed into the tissue of the petiole and borne along with it to a certain extent, and finally become an unwilling part of the leaf stalk.

Trifling as this observation of successive series of buds, one above another, in *Gymnocladus* may seem to be, it may have a very important bearing on our knowledge of the formation of buds. We have been taught that the leaf is the parent of the bud, and an axial bud and leaf are always associated. True, physiologists have noted other buds proceeding from stems and roots; but they have made short work of this mystery by at once deciding that there are two distinct species of buds, and they have termed these leafless affairs adventitious buds; but in the case of *Gymnocladus* we see that of the three buds, one above another, — and the upper one in strong shoots, often an inch away from the lower one, — it is this one the farthest away from the leaf axis which is the strongest. If the leaf exerted any influence, the bud nearest to the leaf axis should derive the most benefit; and further we see in Cassia that instead of the leaf aiding in the development of the bud, it is the direct agent in arresting its growth, and is no doubt also the agent in causing the lower buds of *Gymnocladus* to be weaker than the upper ones.

These series of buds have been singularly overlooked by botanical observers, and therefore the unmistakable voice in which they speak to us has remained unheard. We find them in other plants of very different families. Particularly do they exist in the most vigorous forms of Carya, and Juglans, amongst the *Corylaceæ;* and in Ericaceous plants we find them in *Itea virginica*, in which the upper bud the farthest away from the leaf axis is very fully developed.

I hesitate about offering theories so revolutionary as those to which my observations seem occasionally to tend. I hope the reader will not dwell so much on my explanations of the facts as on the facts themselves. Examine them and possibly a much better theory than my own may be evolved. I chiefly desire to call attention to facts which seem to have been overlooked.

NOTE — Since this paper was read Dr. Geo. Engelmann has pointed out to the author another remarkable instance in *Cornus paniculata* L'Her. There are two buds here; the upper one pushes into growth the same season, and continues the axillary growth of the plants; the lower one, next to the axil of the leaf, remains alive for many years, but rarely grows more than enough to always keep it just above the level of the bark. Also Dr. E. points out that there are three buds, one above another, in *Lonicera Xylosteum* Juss. (I find there are *five*, but two do not get through the bark) but the order of vigor is inversed, the strongest being near the base of the leaf. This observation does not affect the deduction that the leaf has no influence in the production of the buds, — that the leaf is a coincidence with, and not a cause of the bud *or buds*, — but this remarkable exception shows that the whole subject is worth deeper research than bestowed by the author in his brief paper.

IV. ETHNOLOGY.

1. ON THE DISTRIBUTION OF THE NATIVE TRIBES OF ALASKA AND THE ADJACENT TERRITORY. By W. H. DALL, of Washington, D. C.

THE principal authorities on the Ethnology and Philology of Russian America, are the works of Count Admiral von Wrangell, and H. J. Holmberg. The former, republished from the *Memoirs of the Imperial Academy of Science*, edited by Baer, and with additions and an appendix by Baer and Helmersen, was issued at St. Petersburg in 1839. Holmberg's work first appeared in the *Acts of the Finnland Scientific Society*, and was published at Helsingfors, under the title of an *Ethnographic sketch of the People of Russian America*, in 1855. This embodied all the additions that had been made by the few explorers since Wrangell's time, and fairly represents the knowledge possessed by ethnologists, in regard to the inhabitants of Alaska, up to a very recent date. From personal observation, during several years exploration in that country, I am enabled to correct many errors, and add to the stock of knowledge of the subject, much new information in regard to their distribution; the more important part of which is embodied in this paper. Holmberg* divided the native inhabitants of Alaska into four groups:—1. Thlinkets (Thlinkilthen); 2. Koniags (Konjagen); 3. Tnaina (Thnaina), or Kenaians; 4. Aleutians (Aleuten); and these groups again into others equivalent to their tribal organizations, as follows:—

Group first into:—1. *True Thlinkets*, extending from the Nasse River to Mt. St. Elias; and the 2. *Ugalentze*, whom he describes as visiting Kayak island in the winter, and spending their summers on the banks of the Copper River.

Group second:—1. *True Koniags*, or inhabitants of the island of Koniag, or Kadiak; 2. *Tchugatches*, from Prince William Sound, along the south shore of the peninsula of Aliaska, except the east shore of Cook's inlet; 3. *Aglegmutes*, inhabiting the north side of Aliaska, part of Bristol Bay, and the mouth of the river Nushergak; 4. *Kiataigmutes*, between the last, on the coast; and 5. *Kuskokwigmutes*, on the Kuskoquin River, from Fort Kolmakoff to the sea, and also on the island of Nunivak; followed on the coast by the 6. *Agulmutes;* 7. *Magemutes;* 8. *Kwikhliuagmutes;* and 9. *Kwichpagmutes*, which occupy the delta of the Yukon River, followed by the 10. *Tschnagmutes*, in Norton Sound, and 11. *Pastolikmutes*, at the mouth of the Pastolik River; the 12. *Anlygmutes*, on Golofnin Bay, north of Norton Sound, and lastly the 13. *Mauegmutes*, between Norton Sound and Kotzebue Sound.

Group third:—1. *Yunnakakotana*, on the Nulato and Koyoukuk Rivers; 2. *Yunnachotana*, on the Yukon River; 3. *Inkiliks*, on the Yukon, south of Nulato; 4. *Yugelnutes*, on the lower Yukon, in the Shageluk slough and mouth of the "Innoko" River; 5. *Inkalikluaten*, beyond the "Innoko;" 6. *Tlegonkotana*, on the river "Tlegon;" 7. *The true Kenaians or Tnaina*, on the peninsula of Kenai; 8. *Kolshina*, on the upper Kuskoquim and Atna Rivers.

Group fourth:—1. *Unalashkans*, or Fox Island Aleutians; 2. *Atkans*, or Andreanoff islanders.

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*The difficulty of obtaining access to both the above mentioned works is my excuse for quotation.

This classification needs very extensive revision. Holmberg was misled, partly by the exaggerated and unreliable reports of Zagoskin, the first Russian explorer of the Yukon Valley. It must also be remembered that all his information was derived at second hand, and much of it from publications by unscientific persons and ignorant traders.

The inhabitants of Alaska and the adjacent territories may be divided into two great groups; those who belong to the aboriginal American stock, whom we are accustomed to designate as Indians; and those scattered along our northern coasts from Greenland to Berings Strait, and for whom we have as yet no general term, but who have been called Eskimo, Aleutians; and on the Asiatic side of the straits, Tuski and sedentary Chukchees. This last great group I propose to designate as Orarians; * a single term being needed in generalization, and none of those in use being sufficiently comprehensive for the purpose. The Orarians are distinguished by (1) their language of which the dialects in construction and etymology bear a strong resemblance to one another, throughout the group, and differ from the Indian dialects, as strongly; (2) by their distribution; always on islands, or confined to the sea coasts; sometimes entering the mouths of large rivers, as the Yukon, but only ascending them for a short distance, and as a rule, avoiding the wooded country; (3) by their habits, more maritime and adventurous than the Indians; following, hunting and killing, not only the small seal, but also the sea lion, and walrus. Even the great Arctic bowhead whale, frequently succumbs to their preserving efforts; and the harpoon now universally used by whalers, having superseded the old fashioned article, is a copy in steel of the bone and slate weapon which the Eskimo have used for centuries; (4) by their physical characteristics, a light fresh yellow complexion, fine color, broad build; and especially the largely developed coronal ridge, and an obliquity of the arch of the zygoma. I am informed by that eminent craniologist, Dr. Otis of the U. S. Army Medical Museum, in Washington, who has handled perhaps as many aboriginal American crania as any living ethnologist, that the cranial peculiarities, referred to above,

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* From *ora*, a coast, in allusion to their invariable coastwise distribution.

are common to all Orarian skulls, and form a ready means of distinguishing them, being only shared by the northern moundbuilders, who were, perhaps their ancestors.

They are confined to the coasts and islands of northern America, Greenland and the extreme north-eastern portion of eastern Siberia, near Bering Strait.

They are known to the northern Tinneh or Chippewyan Indians as "Uskeemé," or sorcerers, and a belief exists among all the Indian tribes acquainted with them, that they are possessed of supernatural powers. This belief is not unnatural, when we compare the stupid and indolent Indian, gorging or starving by turns, with the agile Eskimo in his kyak, seldom, at least in the more favored regions of Alaska, without a reserve supply of food in his storehouse; and as much at home on the waves as a seabird.

The tribes of this group in north-west America and north-east Siberia, may be divided into three lesser groups.

1. Eskimo.
2. Aleutians.
3. Tuski.

The Eskimo tribes are scattered along the Arctic coast very sparingly. They call themselves *Innuit* and take for a more specific designation the name of the locality where they live, as *Unalaklik*, changing the termination so as to make an adjective *Unalakligmute*, applicable to a single man or woman, and of which the plural is *Unalakligmunés*. They have also tribal names, indicating the inhabitants of a certain tract of country. The tribal lines are very faint and they intermarry without scruple; although there does not seem to be any system like that of the totems, among the whole of this group. South of Pt. Barrow the following tribes may be distinguished:

1. *Kaviagmutes.*—They inhabit the peninsula between Kotzebue and Norton Sounds, which is called by them Kaviiak.

2. *Okeeogmutes.*—These inhabit the islands of Bering Strait, and perhaps St. Lawrence.

3. *Mahlemutes.*—Inhabiting the neck of land between Kotzebue Sound and Norton Bay; their chief village is *Attenmute* on the divide.

4. *Unaligmutes.*—Comprises those living on the shores of

Norton Sound, and south on the coast to the Yukon-mouth; comprising beside others, Holmberg's Nos. 10 and 11 of his second group. The names which he uses are mere local designations, hardly subtribal in value.

5. *Kwikhpágmutes*, or *Ekogmutes.*—Inhabit the delta of the Yukon and are found some fifty miles into the interior where the delta begins. They are called *Premorska* by the Russians, meaning "people by the sea," and take their name from one of the mouths of the Yukon, which is called the Kwikhpák. Those living on the Kusilvak mouth are known as Kusilvágmutes.

6. *Mágemutes.*—Or "mink people," live south-west of the Yukon mouth between it and Cape Romanzoff. The previously mentioned tribes all use the labrets, one on each side, just below the corner of the mouth. The men only wear them. In this tribe, however, they have a different fashion. The women wear two "C" shaped ivory hooks, with the points projecting in front, under the middle of the lower lip. They get their name from the abundance of mink in the region they inhabit, almost to the exclusion of other fur animals.

7. *Agulmutes.*—Occupying the region between the Kuskoquim and Cape Romanzoff, and the island of Nunivak. They are a very shameless and filthy race; nor so ingenious as those on either side of them, except in the matter of carving ivory, in which they excel.

8. *Kuskwógmutes.*—Inhabit the mouth and lower banks of the Kuskoquim River.

9. *Nushergagmutes.*—Inhabit the shores of Bristol Bay, near the mouth of the Nushergak River.

10. *Oglemutes.*—Are found on the east shore of Bristol Bay, south of the last and on the north coast of Aliaska peninsula.

11. *Koniágmutes.*—Occupy the south coast of Aliaska eastward to the sixtieth degree of latitude, the island of *Kadiak* (originally *Koniag*) and the adjacent small islands of the *Koniag* or *Kadiak* archipelago.

12. *Chugachigmutes.*— Are found on the south and east shore of the Kenai peninsula and the shores of Chugach Bay, better known as Prince William Sound.

13. *Ugalakmutes.*—The existence of an Eskimo tribe in

the vicinity of Mount St. Elias, is demonstrated by a vocabulary furnished Mr. Gibbs, by the officers of the Russian American Company. Kayak, the name of a small island, said to be occupied by an Indian tribe during the winter, is evidently of Eskimo extraction. This is the last Eskimo tribe, going south on the north-west coast.

The Aleutians may be divided into two groups, which, however, from the deportation of Aleuts by the R. A. Co., and their arbitrary establishment of villages at one time, and as arbitrary destruction of them at another,—have lost much of their distinctness. They are the

1. *Unalashkans.*—Who inhabit the Fox Islands; principally on Unimak, Unaláshka, Umnak and Akhun, and

2. *Atkans.*— Or Andreanoff islanders, who inhabit the islands of Atka, Amlia, Adák and Attú.

Finally the last group of this race, which has been graphically described by Lieut. Hooper, R. N., and who have been described as sedentary or fishing Chukchees (which name has a numerous variety of spelling) Chukluk, or Namollo, and Tuski. Their language at once distinguishes them from the true Chukchee, or "deer-men," as they call themselves, and their physiognomy is different. They differ from Eskimo (with whom they have been at war since 1630, and perhaps for as many more centuries) in not wearing labrets, and in many respects relating to their mode of life. Their generic name is *Yut*, evidently derived from *Innuit* "people." Those on Seniavine strait call themselves *Chuklukmutes*, but they are so few in number and occupy such a small extent of territory, that it is hardly worth while to do more than adopt the general name of

1. *Tuski.*—Proposed by Lieut. Hooper. They extend along the shores of the country between Anadyr Gulf and Kuluchinskaia Bay and Bering Strait.

The Indians are not so easy to group, without more division than perhaps is justified, by our present state of knowledge of some of the tribes. So far as Alaska and the adjacent American territories are concerned, the Thlinkets from one very distinct group, and many points of resemblance seem to suggest that the Ingaliks and Koyukuns, as well as the Atna or Copper River tribes, and the Indians of Kenai should form, with a subdivision for the Kutchin tribes, another; while the Haidahs of the extreme southern part of the Alexander Archipelago, belong with those of Queen Charlotte's Islands to still another group. There are several extra-limital groups requiring notice. Commencing at the south on the coast, we have south of our boundary on the mainland, the *Chimsyans;* and on Queen Charlotte's Islands the Haidahs, who extend across Dixon's entrance, and have several villages on our islands. They are more properly

1. *Kygáni.*—And are only found at this point in our territory.

We next find the Thlinkets inhabiting the Alexander Archipelago and adjacent shores of the mainland. *Kwan* with them signifies "people," and is affixed to the local designation. Of some of the tribes in this and the next group, we only know the Russian names which may or may not, be those by which they call themselves. The Thlinkets may be divided as follows:

1. *Sitka-kwan.*—Occupying Baranoff, and the adjacent islands of the archipelago and having their principal village near Sitka.
2. *Stakhin-kwan,*—Or Indians inhabiting the mouth of the Stikine River and the adjacent coast.
3. "*Yakutats.*"—Or residents in the vicinity of Bering or Yakutat Bay. They are allied by their language to the two previously mentioned tribes, but little is known of them.

We now reach the southernmost point of appearance on the coast of the western Tinnéh tribes, which may be separated into three general groups; those calling themselves *Kutchin* (people), and those who designate themselves *Tinnéh* or *Tahna,* with the same significance. The first of the Tinneh tribes belongs to the latter group, using the word *táhna,* as do most of those near the coast, while those on the upper Yukon and interior are "Kutchin," while those still farther east on the Mackenzie are *Tinneh.* In this general list I shall regard them as a whole.

1. "*Ugalensé.*"—This is the name used by Russian and German authorities to designate a tribe that has its winter quarters on Kayak Island, and resides on the lower banks of the Atna or Copper River in summer. These are referred to

the Thlinket family by Holmberg, but perhaps belong rather with the Tinneh.

2. "*Ah-tená*."—Living on the upper Copper River, not to be confounded with the Kutchin tribes of the upper Yukon who visit the head-waters of the Copper River to trade, and are called *Kolchina* or *Kolshina* by the Russians; who apply that term to many tribes of whom they know very little.

3. "*Kenai-tená*."—*Thnaina* on Tenahna of Holmberg, inhabit the shores of Cook's inlet and the country, to the Alaskan Mountains.

4. *Kaiyuh-khotaná.*—(Lowlanders) or Ingaliks. This great tribe speaks essentially one dialect and includes Nos. 3, 4, 5, 6, 7 and 8 of Holmberg's third group of Thnaina. The "Innoko" River is really the Shageluk, and the "Tlegon" "Tatsheg-no," etc., are mythical streams, running through a country which has never been penetrated by white men or Russian creoles, and reported by the Indians to be nearly destitute of fish and game, and hence uninhabited.

5. *Koyúkokhotáná.*—Or Koyukun Indians, inhabit the region north of the great bend of the Yukon on the Koyukuk River. The Nulato Indians, whose language bore more resemblance to the Koyukun dialect than any other Ingalik branch, were exterminated by the Koyukuns in 1851, with the exception of a few children.

6. *Unakhotána.*—(Far off people) inhabit the banks of the Yukon above Koyoukuk Mountain, to the mouth of the Tananah River. There are very few villages, and these, as well as all the Kutchin and Ingalik tribes, living on the river, call themselves *Yukonikhotana* or "men of the Yukon."

7. *Kutchá kutchin* (Loucheux).—Inhabit the country near the junction of the Rat River and the Yukon. These and the following tribes are migratory, following the deer and pitching their lodges anywhere; while the Ingaliks and Koyukuns have well built permanent houses, which they occupy at least for a part of the year.

8. *Tenan kutchin.*—(Mountain men) are found on the banks of the Tananah River, which has never been explored by white men. They come, however, to trade with both Russians and Hudson Bay traders at *Nuklakahyèt.*

9. *Natché kutchin.*—(Wanderers) north of the Yukon and Rat Rivers about longitude 144° W.

10. *Vunta kutchin.*—(Loucheux) on the Rat River farther up, in the H. B. Territory.

11. *Tuk-kuth kutchin.*—(Rat people) occupy the headwaters of the Rat River; on the other hand going up the Yukon.

12. *Han kutchin.*—(Wood people) or Gens de Bois, about two hundred miles above Fort Yukon on the Yukon and beyond them.

13. *Tutchon Kutchin.*—(Crow people) or Gens des Foux on the Yukon, nearly to the site of Fort Selkirk, at the junction of the Lewis River and the Pelly, and finally we find at the headwaters of the Yukon the

14. *Abba-to-tenah.*—Or *Nehaunee* Indians, who are found along the coast range, and parallel with it; and by crossing the same we reach our starting point again among the Stikine Thlinkets.

The limits of this paper will not admit of an elaborate description of the several tribes, but a few remarks of a general nature may not be entirely out of place. The accompanying vocabularies will show more clearly than pages of argument or explanation, the relations which exist between the several dialects. These are only given as specimens for comparison, the bulk of material being in preparation for publication.

It is to be hoped that measures will be taken at once to prevent the utter loss of the traditions and ancient religious rites of the Aleuts and Koniagemutes. These rites were put down eighty years ago, by the Russian missionaries, almost literally with fire and sword. At the same moment that the traders deprived them of their liberty, in order that they might be forced to hunt fur animals for the benefit of the Russians, the priests fired with ardor, and the hopes of promotion in the church, burned their idols, and destroyed, wherever possible, the gorgeous paraphernalia in which the mysterious rites of their ancient religion were performed. These rites were secretly kept up for forty years, but were at last totally suppressed, and the only relics remaining are a few decayed, yet still curious masks, which were placed with the dead, whom the priests did not attempt to disturb. Had they preserved an account of the religion they destroyed we might forgive them their iconoclasm, but their records only contained lying reports of immense numbers of converts to christianity; which reports were so astounding in their exaggeration that, says the Russian historian, Tikhmenief, "they were received with doubt," at St. Petersburg.

The only means by which any part of these traditions can be preserved, is by obtaining them from a few old men who witnessed in their youth the ceremonies referred to, and have not to this day become emancipated from the attendant superstitions. These old men will soon pass away, and if no steps are taken to prevent it, all knowledge of the ancient Aleutian customs with them. My own opportunities did not allow of my obtaining the desired information.

The Eskimo of Norton Sound, the Yukon-mouth and Kotzebue Sound are fine athletic men, many of them six feet in height, and averaging, I should say, as tall as any civilized race. They are as ingenious, as honest and industrious as the majority of white men, and very far superior to any Indian tribe in the territory. They are great eaters, but no more so than the Indians, and they are by far the cleaner of the two. They fall victims to the use of liquor whenever they can obtain it, which is the only obstacle between them and the hope of ultimate civilization. At no point does there seem to be any intercourse between the Eskimo and Indians except in the way of trade. They never intermarry, and in trading, use a sort of jargon, neither Indian nor Eskimo. Few words, as far as I have been able to find out, are common to the two languages, except *kweényuk* (pipe), which the Indians borrowed from the Eskimo, who were the first to obtain and use tobacco, and *tenékuh* (moose), an Indian word which is used by the Eskimo, as they have no moose and hence no word for it in their country; and a few evidently similar cases.

The Indians who live in the more mountainous regions, and hunt the deer, are active, courageous and prone to war. Those on the other hand who live on the moose, which frequents the lowlands, are comparatively peaceful; while those on the lower Yukon whose diet is almost exclusively fish, are the lowest, most degraded and filthy of all.

A belief in shamanism is common to all, both Indian and

RACE.		
FAMILY.	ALEUTIANS.	
TRIBE.	UNALASKAN.	ATKAN.
Man.	Taiggiach.	Toiooh.
Woman.	Angaginak.	Aiyagar.
Wife.	Agegai.	Aiyagai.
Boy.	Anektok.	Anekthok.
Girl.	Achadok.	Ogegilikin.
Chief.	Tajaghu. Toigon.**	Toigon.**
Water.	Tanach.	Taangak.
Snow.	Kanich.	Kaneek.
Ice.	Kelach.	K'thak.
Rain.	Chichtach.	Chiūtakik.
Land.	Tchikitch.	Chegak.
Island.	Chananak.	Taangik.
Fire.	Nignach.	Kĭgnach.
Reindeer.	Ithayok.	It kayech.
Fish.	Kach.	Koach.
Knife.	Kamlich.	Ungazchiship.
Good.	Macheeselik.	Chizchelik.
Bad.	Macheedolikan.	Malcheeshelika
Big.	Anianach.	Tangocllik.
Little.	Angnunadakalak.	Angonolokn.
Hot.	Akivakselik.	Akvachelik.
Cold.	Kinanach.	Kinganalik.
I.	Tirm.	Keen.
You.	Thinn.	Ingaan.
He, she or it.	Inan.	Ikoon.
Yes.	Ang.	Aang.
No.	Kogcho.	Maselikan.
1.	Atakan.	Attokan.
2.	Alach.	Alluk.
3.	Kankjannoon.	Kankoon.
4.	Sitchin.	Shitchin.
5.	Tchann.	Chang.
6.	Atyoon.	Attoon.
7.	Talann.	Olung.
8.	Kanitchin.	Kamtsching.
9.	Sitchinin.	Sitching.
10.	Atik.	Nasuk.
AUTHORITY.	Saur.	Saur.

*Same in both dialects. Substantive and adjective f

ally wear in the perforated ears and lips pieces of wood, shaped like a bottle cork. The custom is not kept up at present, few of the children having the perforations. The pressure of this plug generally causes the loss of the front teeth, which are pushed out of place. Mr. Hartt gave a graphic description of the appearance of the deformity thus caused.

These Indians sometimes paint not only the face but the body with annatto and a black vegetable dye, but they usually go naked and unpainted. They carry long bows, often exceedingly hard to bend, using arrows of different kinds for hunting and in war. Before the settlement of America by the whites they used cutting instruments of stone. The several tribes are governed by chiefs chosen for their strength and stature. Professor Hartt described their food as consisting of wild animals, including monkeys, lizards, and snakes; they are very fond of the larvæ of beetles found in decayed wood. Bananas, honey, ants, etc., are also used for food. They obtain fire by twirling a dry stick in a small hollow in another. They have only one wife, who is treated very brutally. The women are almost slaves, carrying the burdens and doing all the hard work. Children are generally treated kindly. Their religious ideas are very dubious, they believe in bad spirits, great and small; but they appear to have no idea of a good God. The dead are buried in the wigwam or near it, and the camp is generally deserted. The corpse is buried horizontally without anything in the grave with it, and a fire is sometimes built over the grave to keep off bad spirits. They are strongly suspected of cannibalism. They have very monotonous dances of which they are very fond. The Brazilians have in past years hunted them like dogs and this destruction, with the effects of rum, has almost exterminated the race. The Botocudos are now confined to the forest between the Rio Doce and the Rio Pardo. They resist civilization and christianity, and are sunk in the lowest barbarism.

The speaker gave a minute description of their language, which is simple and almost without inflections.

TITLES

OF

COMMUNICATIONS.*

A. MATHEMATICS, PHYSICS AND CHEMISTRY.

1. On the Determination of the Mechanical Equivalent of Heat by means of the modern ice and cooling Machines. By P. H. Van der Weyde.

2. The Spectral Bands considered as harmonies of one or more fundamental longer waves, laying beyond in the invisible calorific rays. By P. H. Van der Weyde.

3. Atomic Volume and Atomic Distances of the Crystallized A B_3 C. By Gustavus Hinrichs.

4. On the Manufacture and Uses of Amalgams of the Alpali-Metals. By Henry Wurtz.

5. On the Influences which rule Natural Forces. By Henry Wurtz.

6. On the Nature of Metallicity. By Henry Wurtz.

7. On the Conservation of Force. By H. F. Walling.

8. Elemental Fibres, illustrated by models. By H. F. Walling.

9. The Classification of the Elements of Matter. By Charles A. Seely.

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* The following papers were also read: of some, no copy has been received for publication; of others, it was voted that the title only should be printed. No notice, *even by title*, is taken of articles not approved.

10. THE VOLUMETRIC DETERMINATION OF CARBONIC ACID. By CHARLES A. SEELY.

11. ON THE SOURCE OF THE COLOR OF CHLOROPHYLE, AND THE REDUCTION OF CARBONIC ACID IN PLANTS BY PHOSPHATE OF PROTOXIDE OF IRON, AS THE FIRST STEP IN THE PRODUCTION OF ORGANIC BODIES CONTAINING CARBON. By E. N. HORSFORD.

12. ON THE RELATIONS OF WASTE AND REPAIR TO THE METAMORPHOSES OF THE PHOSPHATES. By E. N. HORSFORD.

13. THE SOURCE OF SALT–WATER AT THE BOTTOM OF MYSTIC POND. By E. N. HORSFORD.

14. ON A NEW METHOD OF PRODUCING BY THE ELECTRIC SPARK FIGURES SIMILAR TO THOSE OF LICHTENBERG. By E. W. BLAKE.

15. ON THE ETHEREAL MEDIUM. By SAMUEL D. TILLMAN.

16. ON A SELF-RECORDING PSYCHROMETER. By SAMUEL TILLMAN.

17. SOME RESULTS OF THE DISCUSSION OF THE BOSTON DRY DOCK TIDE OBSERVATIONS. By WILLIAM FERREL.

18. ON THE VELOCITY OF THE ELECTRIC CURRENT OVER TELEGRAPH WIRES. By G. W. HOUGH.

19. ON THE TOTAL ECLIPSE OF AUG. 7. By G. W. HOUGH.

20. NOTES ON THE CHEMISTRY OF COPPER. By T. STERRY HUNT.

21. NEW DEVICES FOR PRODUCING AND MANAGING INTENSE HEAT. By CHARLES A. SEELY.

22. FORMULA FOR COMPUTING THE TIME OF AXIAL ROTATION OF ANY PRIMARY PLANET, ITS DENSITY, AND THE RELATIVE FORCE OF GRAVITY AT ITS SURFACE, BEING GIVEN. By IRA WANZER.

23. AN IMPROVED METHOD OF OBSERVING METEORIC SHOWERS. By DAVID MURRAY.

24. HINTS TOWARDS AN EXPLANATION OF THE CORONA IN SOLAR ECLIPSES. By DAVID MURRAY.

25. PLANETARY INFLUENCE ON RAINFALL AND TEMPERATURE. By PLINY E. CHASE.

26. ON THE USE OF THE THERMOMETER TO DETERMINE THE PERIOD OF SOLAR ROTATION. By PLINY E. CHASE.

27. REMARKABLE CASE OF FREEZING FRESH WATER PIPES IN SALT WATER. By W. W. WHEILDEN.

28. ON THE GROUPING OF AEROLITES. By J. E. OLIVER.

29. LONGEVITY OF AMERICAN SHIPS, WITH THE APPROXIMATE LAW OF THEIR LOSS OR DECAY. By E. B. ELLIOTT.

30. ON THE VALUES OF THE STANDARD MONETARY UNITS IN WHICH SECURITIES OF THE UNITED STATES ARE QUOTED IN CERTAIN COMMERCIAL CENTRES OF EUROPE. By E. B. ELLIOTT.

31. ON SOME FURTHER EVIDENCE OF THE EXISTENCE OF A SYSTEM OF ARCTIC WINDS. By JAMES H. COFFIN.

32. ON THE IMPERFECT WHITENESS OF SNOW. By J. E. OLIVER.

33. ON THE PRESENT CONDITION OF LIGHT HOUSE ILLUMINATION IN THE UNITED STATES. By JOSEPH HENRY.

34. ON THE SOLAR ECLIPSE, AND THE OUTLINES OF THE CORONA AS OBSERVED AT DES MOINES. By THOMAS BASSNETT.

35. CHEMICAL AND MECHANICAL MEANS AS A PROTECTION OF LIFE AND PROPERTY FROM FIRE ON RAILWAY CARS. By J. F. BOYNTON.

36. THE LAW OF ACCIDENTS. By G. A. LEAKIN.

37. A NEW METHOD OF RENDERING THE NEEDLE OF A GALVANOMETER DEFINITELY ASTATIC. By M. G. FARMER.

38. SMITH'S VULCANITE ELECTRICAL MACHINE, WITH ATTACHED CONDENSER. By M. G. FARMER.

39. THE AMERICAN COMPOUND TELEGRAPH WIRE, REFERRED TO THE BRITISH ASSOCIATION UNITS OF RESISTENCE. By M. G. FARMER.

40. On an Improved Construction of the Holtz Electrical Machine adapted for the Analysis of the Phenomena of this variety of Machine, and for Classroom use. By R. E. Rogers.

41. On the Total Eclipse of August 7, 1869. By Benjamin Peirce.

42. On Quintuple Algebra. By Benjamin Peirce.

43. The Reactive Force of a mass composed of many noncohering particles or parts. By J. D. Warner.

44. On the Audible Transmission of Musical Melodies by means of the Electric Telegraph. By P. H. Van der Weyde.

45. Electricity not a self existent fluid, but a mode of motion of matter. By P. H. Van der Weyde.

46. Photographing Objects of Natural Size without a Camera. By T. Gaffield.

47. On the Proper Monetary Unit. By J. F. Holton.

48. On the Abolition of Months. By J. F. Holton.

49. On Oceanic Communication. By W. K. Hopkins.

50. The Numerical Method of Criticism. T. M. Coan.

51. On the Resolution of Microscopic Test Objects. By A. M. Edwards.

52. Some Observations, at Montreal, on the Solar Eclipse with Photographs taken by William Notman. By Charles Smallwood.

53. Some Remarks on an Opaque Illuminator, applied to an Immersion Objective, and an Immersion Objective of Long Focal Distance. By E. Bicknell.

B. NATURAL HISTORY.

1. On the Arrowheads of the American Indians and Aborigines. Illustrated by specimens. By John A. Warder.
2. Mammarian Types. By Samuel J. Wallace.
3. Description of a New Species of Chiton. By William Prescott.
4. On the Non-Fossiliferous Rocks of New England. By N. T. True.
5. Exhibition of a few interesting implements collected by R. W. Haskins from Indian graves on the banks of the Ohio, with special reference to the boring of holes in stone implements. By F. W. Putnam.
6. On Embryonic Characters in American Salamanders. By E. D. Cope.
7. On two new genera of Extinct Cetacea. By E. D. Cope.
8. Experiments in connection with the case of Mon. Groux of Hamburg. By J. Baxter Upham.
9. On the Deposits of Fluviatile and Lacustrine Gold. Henry Wurtz.
10. On the Discovery of the Ammonoosuc Gold Field. By Henry Wurtz.
11. Notes on the Geology of Hoboken. By Henry Wurtz.
12. Studies of the Red Sandstones of New Jersey. By Henry Wurtz.
13. Note upon the Palæotrochis. By Henry Wurtz.
14. On the Early Stages of Brachiopods. By E. S. Morse.
15. Popular Science. By Mrs. Lincoln Phelps.

16. THE AMMONOOSUC GOLD FIELD IN NEW HAMPSHIRE AND VERMONT. By C. H. HITCHCOCK.

17. INDIAN MIGRATIONS. IN FOUR SECTIONS. SEC. 1. PHYSICAL GEOGRAPHY OF NORTH AMERICA, WITH REFERENCE TO NATURAL HIGHWAYS; AND MEANS OF NATURAL SUBSISTENCE AFFORDED BY ITS AREAS. SEC. 2. AGRICULTURAL SUBSISTENCE, AND THE CHARACTER AND EXTENT OF INDIAN AGRICULTURE. SEC. 3. MIGRATIONS OF ROVING AND PARTIALLY VILLAGE INDIANS; DEDUCED FROM LANGUAGES, TRADITIONS, AND KNOWN MIGRATIONS. SEC. 4. MIGRATION OF VILLAGE INDIANS; AS DEDUCED FROM THE SAME SOURCES. By L. H. MORGAN.

18. COMPRESSION AS AN AGENT IN GEOLOGICAL METAMORPHISM, WITH ILLUSTRATIONS OF DISTORTED PEBBLES IN CONGLOMERATES. By GEORGE L. VOSE.

19. ON THE PLUMAGE OF TERNS. By MISS GRACE ANNA LEWIS.

20. THOUGHTS ON THE STRUCTURE OF THE ANIMAL KINGDOM. By MISS GRACE ANNA LEWIS.

21. ON A REMARKABLE LOCALITY OF VERTEBRATE REMAINS IN THE TERTIARY OF NEBRASKA. By O. C. MARSH.

22. DISCOVERY OF THE REMAINS OF THE HORSE AMONG THE ANCIENT RUINS OF CENTRAL AMERICA. By O. C. MARSH.

23. ON SOME NEW MOSASAUROID REPTILES FROM THE GREENSAND OF NEW JERSEY. By O. C. MARSH.

24. ON THE METAMORPHOSIS OF SIREDON INTO AMBLYSTOMA, By O. C. MARSH.

25. ON THE GEOLOGY OF VENEZUELA. By R. P. STEVENS.

26. OBSERVATIONS ON A NEW GENUS OF POLYZOA. By ALPHEUS HYATT.

27. REMARKS ON TRICHINA SPIRALIS. By J. BAKER EDWARDS.

28. ON THE ACCENT OF SPEECH AND ITS RELATION TO THE VITAL FUNCTIONS. By J. STANLEY GRIMES.

29. ON THE HOMOLOGIES OF THE PALÆCHINIDÆ. By ALEXANDER E. R. AGASSIZ.

30. NOTICE OF FOSSILS FROM TABLE MOUNTAIN, CALIFORNIA. By W. P. BLAKE.

31. SUMMARY OF RESULTS OF A LATE GEOLOGICAL RECONNOISSANCE OF LOUISIANA. By E. N. HILGARD.

32. HINTS ON THE STRATIGRAPHY OF PALÆOZOIC ROCKS OF VERMONT. By J. B. PERRY.

33. PHYSICAL GEOGRAPHY AMONG THE ABORIGINES OF NORTH AMERICA. By N. T. TRUE.

34. ON SURFACE CHANGES IN MAINE INDICATING THE LENGTH OF TIME SINCE THE CLOSE OF THE QUATERNARY PERIOD. By N. T. TRUE.

35. ON NORITE OR LABRADORITE ROCK. By T. STERRY HUNT.

36. ON THE GEOLOGY OF NORTH-EASTERN AMERICA. By T. STERRY HUNT.

37. ON ANCIENT EROSIONS IN THE ST. LAWRENCE VALLEY. By T. STERRY HUNT.

38. POST-GLACIAL FOSSILS AT HOBOKEN, N. J. By R. P. STEVENS.

39. ON THE GEOLOGY AND PHYSICAL GEOGRAPHY OF A PART OF THE COAST OF MAINE. By JOHN JOHNSTON.

40. ON THE DISTRIBUTION OF COAL, IRON, AND THE PRECIOUS METALS, IN CHINA. By ALBERT S. BICKMORE.

41. ON THE ARCTIC OCEAN, THE MOVEMENTS OF ITS WATERS, TRIBUTARIES, AND THE APPROACH OF THE GULF STREAM. By W. W. WHEILDEN.

42. ON CERTAIN PECULIARITIES IN THE DISTRIBUTION OF MARINE LIFE ON THE SEA-BOTTOM OF THE BAY OF FUNDY. By A. E. VERRILL.

43. ON THE RELATIONS OF THE GEOLOGY OF OHIO TO THAT OF THE ADJOINING STATES. By J. S. NEWBERRY.

44. ON THE FLORA AND FAUNA OF THE FRESH WATER TERTIARIES OF OREGON AND IDAHO. By J. S. NEWBERRY.

45. ON THE TERTIARY FLORA OF ALASKA. By J. S. NEWBERRY.

46. ON THE RARITAN CLAYS OF NEW JERSEY. By J. S. NEWBERRY.

47. ON NEW SPECIES OF FISHES OBTAINED BY PROF.. ORTON IN THE VALLEYS OF THE MARONON AND NAPO. By THEODORE GILL.

48. ON THE SYSTEMATIC RELATIONS OF THE LAMARCKIAN PTEROCERÆ. By THEODORE GILL.

49. PRELIMINARY NOTICE OF THE LAMELLIBRANCHIATES OF THE UPPER HELDERBERG, HAMILTON, AND CHEMUNG GROUPS. By JAMES HALL.

50. RESULTS OF A LATE GEOLOGICAL RECONNOISSANCE IN LOUISIANA. By E. W. HILGARD.

51. NOTE ON A PHASE IN THE REPRODUCTION OF A CONFERVACEOUS ALGA BELONGING TO THE GENUS ŒDOGONIUM. By A. M. EDWARDS.

52. ON SOME POINTS IN THE GEOLOGY OF NORTH CAROLINA. By W. C. KERR.

53. ON THE PHYSICAL GEOGRAPHY AND GEOLOGY OF BRAZIL. CHARLES F. HARTT.

54. ON BRAZILIAN DRIFT. By CHARLES F. HARTT.

55. THE HOMOLOGIES AND GENERAL STRUCTURAL RELATIONS OF THE POLYZOA. By ALPHEUS HYATT.

56. NOTICE OF SOME NEW FOSSIL PLANTS FROM GASPE, DISCOVERED BY PROF J. W. DAWSON. By J. S. NEWBERRY.

57. ON THE DYESTONE FOSSIL IRON ORE IN PENNSYLVANIA. By J. P. KIMBALL.

58. OBSERVATIONS ON THE LANGUAGES OF SOUTH AMERICA AND THE CLASSIFICATION OF THE INDIAN NATIONS THEREOF. By PORTER C. BLISS.

59. A CONJECTURAL EXPLANATION OF THE USES OF THE EMBANKMENTS OF THE MOUND BUILDERS. By L. H. MORGAN.

60. ON THE ORIGIN OF MUSCULAR AND MENTAL FORCE. By GEORGE F. BARKER.

61. THE AINOS, OR HAIRY MEN OF YESSO, SAGHALIEN, AND THE KURILE ISLANDS. By A. S. BICKMORE.

62. ON THE CLASSIFICATION OF THE DIURNAL LEPIDOPTERA. By S. H. SCUDDER.

63. THE MORPHOLOGY OF THE ABDOMINAL APPENDAGES OF BUTTERFLIES. By S. H. SCUDDER.

64. THE VALUE OF THE CHARACTERS DRAWN FROM THE EXTERNAL ARMATURE OF LEPIDOPTEROUS LARVÆ. By S. H. SCUDDER.

65. THE INTERNAL ANATOMY OF DANAIS ERIPPUS. By S. H. SCUDDER.

66. A CLASSIFICATION OF THE EGGS OF BUTTERFLIES. By S. H. SCUDDER.

67. EVIDENCES OF HIGH ANTIQUITY IN THE KJŒKKENMŒDDEN DEPOSITS OF NEW ENGLAND. By E. S. MORSE.

68. ON LAWS OF TRADE. By E. B. ELLIOT.

69. ON THE PRODUCTIVENESS OF THE HUMAN RACE. By J. F. HOLTON.

70. ON CLEANING GUANOS SO AS TO OBTAIN THE MICROSCOPIC ORGANISMS IN THEM. By A. M. EDWARDS.

71. SOME REMARKS ON THE INFUSORIAL DEPOSITS OF NORTH AMERICA. By A. M. EDWARDS.

72. COMPARISON OF THE CORAL FAUNÆ OF THE ATLANTIC AND PACIFIC COASTS OF THE ISTHMUS OF DARIEN, AS BEARING ON THE SUPPOSED FORMER CONNECTION BETWEEN THE TWO OCEANS. By A. E. VERRILL.

EXECUTIVE PROCEEDINGS

OF

THE SALEM MEETING, 1869.

HISTORY OF THE MEETING.

THE Eighteenth Meeting of the American Association for the Advancement of Science was held at Salem, Mass., commencing on Wednesday, August 18, and continuing to Tuesday Evening, August 24.

Two hundred and forty-four names are registered in the book by members who attended this meeting. One hundred and fifty new members were chosen, of whom one hundred and eleven have already signified their acceptance by paying the annual assessment, and, when practicable, signing the constitution. One hundred and sixty-two papers were presented, many of which were read, and some of them discussed at length.

The sessions of the Association were held in the County Court Houses, and in the Vestry and Church of the Tabernacle Society. At about 10 o'clock A.M. on Wednesday the members were called to order by Dr. B. A. Gould, the retiring President, who, in a few appropriate words, introduced the President elect, Col. J. W. Foster. At the request of the Standing Committee, prayer was offered by Rev. E. S. Atwood.

The chairman of the Local Committee, Dr. Henry Wheatland, then introduced the Association to His Honor Mayor Cogswell, of Salem, speaking as follows:—

Mr. Mayor :—Allow me to introduce to you the President and members of the American Association for the Advancement of Science.

This Association dates its origin to 1840, when, on the 2d of April of that year, some eighteen gentlemen, principally connected with the several State Geological Surveys then in progress, met in the hall of the Franklin Institute, Philadelphia, at the request of the members of the New York Survey, and organized an association under the name of "The Association of American Geologists." At the meeting in Boston, in 1842, it was decided to enlarge the objects so as to embrace the collateral branches of natural science, the name being changed so as to read "The Association of American Geologists and Naturalists." At the meeting in 1847, the objects were still farther enlarged so as to include all departments of science. A new organization was effected under the present name. Thus, in the spirit of this enlarged constitution, the Association opened its doors wide for the admission of students in every department of positive science, convinced that the time had come for thus extending its operations. This Association is republican in its organization and migratory in its visits; meetings have been held in various cities of the Union annually, except during the years 1861-65, when they were suspended in consequence of the great crisis through which the country has recently passed, the meeting for 1861 having been appointed for Nashville.

Twenty years since, the day following the adjournment of the Cambridge meeting, the Association visited Salem in the steamer R. B. Forbes, which was placed at its disposal by the kindness of the proprietors, and spent several hours in inspecting the Museum, the rooms of the Institute and other objects of interest. This meeting was long remembered from its many interesting associations.

It is always pleasant at these meetings to witness the assemblage of so many zealous and enthusiastic workers in science, scattered necessarily over a large extent of territory, and kept asunder by distance and the claims of professional duties; laboring amid all the inconveniences of solitude, and isolated from the sympathy and counsel of those engaged in the same glorious enterprise, thus coming together, becoming acquainted with each other's social and scientific worth, comparing notes, and contributing largely to scientific knowledge. May this meeting leave many pleasant associations, and be long remembered as productive of good results, and a lasting friendship between all the members.

Mayor Cogswell responded in the following terms: —

MR. PRESIDENT AND GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: —

In the name of the people of the city of Salem I have the honor to bid you a hearty and most cordial welcome, and to express to you our hope that this visit may be so pleasant and instructive that you may be induced to repeat it at no distant day. I am charged also with the agreeable duty of tendering to you the hospitalities of the city and the courtesies of her citizens. Coming as you do from all parts of the Continent, bringing with you as you do the results of years of scientific study, meeting as you do to discuss the important questions embraced within the objects of your Association, we feel that your presence in our midst is an honor to our city, and that we shall be benefited by your coming. We hope that along our shores you may find objects of interest and instruction, and that the great study of nature and of nature's God in which you are engaged may be promoted thereby. We delight somewhat in our rocky coast, for we believe it has borne hardy sons. We shall delight to show you everything of interest which we have, while from you we shall expect much of knowledge and information. Here, and in this vicinity, as you know, was first planted that deep-seated, earnest, anxious system of religion which developed or was developed by the Puritans, and which has left its impress wherever the son of the Puritan has trod. Religious as our fathers were, however, material considerations were not neglected, and the port of Salem had the honor of first opening up to the new continent the wealth of the Indies and the fruits which have flowed therefrom. Some of this trade has now gone out from us to build up other places, but the city of Salem, with an energy increasing every day, is now devoting herself to industrial pursuits on her own soil, taking her place, as all eastern cities must, as the manufacturer of what the South and West produce. We have also here some old traditions, I believe, of what took place among our people in those earlier days, of which you probably may have heard. The accomplished gentlemen in charge of our County Court records will be pleased to show you, if you will, some of the original documents relating to those mysterious times, which it may interest you to examine. Whatever would have befallen a convention of progressive scientific men in that day it might perhaps be hard to tell; but I can assure you, gentlemen, that this day your convention will be safe and undisturbed. It is not for me, however, to speak the praises of Salem, but rather to extend to you again its welcome. Welcome to our midst; welcome to the duties of the session; welcome to all the pleasure and entertainment and kindness in our power to grant you! From the West I greet you as the representatives of a mighty power in this country, in whose hands almost alone remains the weal or woe of the still great problem of our form of government! From the South I greet you as the representatives of a section which it is my prayer may soon blossom as the rose, and to whose sunny clime and fertile soil it is my heartfelt wish may soon return a wealth, a happiness, and a peace which shall last for ever and ever. From the North and East I welcome you as neighbors; and from the realms of the illustrious Queen I bid you welcome to the vicinity of the birth-place and the home of that distinguished citizen whose world-wide benefaction your Queen has delighted to honor and acknowledge.

At the close of Mr. Cogswell's remarks, President Foster responded, addressing the Mayor and the Association, in the following words: —

Mr. Mayor: — As the official organ of the American Association for the Advancement of Science, I express to you my profound thanks for the cordial welcome extended to us on this occasion. It gives us pleasure once more to meet within the limits of this ancient Commonwealth, illustrious in its historical associations, and in those institutions designed for the cultivation of the intellect, and the alleviation of the ills incident to our common humanity.

It is proper, too, that we meet within the limits of this good old town of Salem; for, years ago, as the Mayor has informed you, its merchants, when they sent forth their ships to the East, which returned freighted with

> —— "the wealth of Ormus and of Ind,"

were wont to dedicate whatever was rare or curious to the cause of science. This was the origin of the East India Museum, the first institution of the kind, I believe, in the United States. The Essex Institute is another expression of the zeal of your people in the cultivation of those arts which dignify and adorn life. The Peabody Academy of Science is a noble monument to the comprehensive beneficence of its founder, and one among the many of those benefactions which have made his name illustrious in both hemispheres.

The American Association, then, take pride in meeting here. It is an organization, catholic in all its aims and objects. In its ranks are enrolled men representing nearly every profession and every portion of the Union. We here meet on common ground—to compare views, to discuss problems, to eliminate truth, to announce results; and, Mr. Mayor, when we shall have closed our deliberations, I doubt not that each one of us will carry to his home kindly remembrances of the courtesy and hospitality of the good people of Salem.

GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—I desire to tender to you my profound thanks for this manifestation of your regard in calling me to preside over your deliberations. It is a position worthy of all aspiration. But the possessor must approach its duties with fear and distrust. It is with these feelings that I present myself before you on this occasion, but I trust that by the exercise of a spirit of strict impartially in the discharge of my duties, I shall win your approbation and support.

The eighteenth annual session of this Association commences under favorable auspices. At its last meeting the attendance was never greater; its treasury never better supplied; and the memoirs, in number, variety, and interest, were never surpassed. There was a spirit of harmony and good fellowship among ourselves, and of zeal and devotion to the cause of science, from which we can draw the happiest auguries.

We have now enrolled in our ranks a class of young men who are better educated, and have had far greater facilities for investigation than were enjoyed by us, their seniors, at their age, and to them we may safely confide the interests of this Association when we shall have rendered up our trust. What to us, at their time of life, was but a glimmering of light, to them is meridian splendor. What to us were but reasonable conjectures, to them are matured results. What we saw as through a glass darkly, they are permitted to see face to face. The verge to which we have attained, after long toil, is to them but the starting point for new explorations into the domain of nature. The future historian in treating of these times will regard this as an age, compared with past ages, when the human mind put forth its most vigorous manifestations, not only in reference to pure science, but also in reference to the practical arts of life. This has been accomplished by a faithful study of the laws of nature, and by acquiring a mastery over physical forces,—thus showing that nature is not like the Delphic Oracle of old which gave forth mysterious utterances and capable of two-fold interpretation, but rather like a beneficent deity, ready to reward each votary who, with all-reverent spirit and all-sentient ear, enters her sanctuary and listens to her teachings.

Many of the Natural Sciences have developed into that beauty and harmony which now characterize them within the lifetime of many of us. Yet what we have accomplished is but the prelude to what shall be accomplished. The Chairman of the Local Committee has referred to the origin of this Association, and has very properly told you that that origin dates back to the year 1840, when less than twenty ardent and devoted men, for the most part engaged in the State Geological Surveys, assembled in the rooms of the Franklin Institute, at Philadelphia, and there organized as the Association of American Geologists. He has traced that organization until it has assumed its present form. I take pleasure in recurring to that early history, because it was an event in American science. The necessity for such an organization was apparent. Geology at that time had hardly assumed the shape of a science. Formations of the same age, and having a wide geographical range, bore different local names; and the entombed organic remains, which have proved the hieroglyphics by which we have been enabled to interpret the physical history of our planet, were then but little known. To compare views, to receive and impart instruction, and fix upon a common nomenclature, was the business of these observers. Each one brought forward the fruits of his observation to contribute to the general fund, —as of old among the Greeks, when a hero died, each warrior brought forward a shield full of earth, and cast upon his remains, until there was erected a mausoleum which rose up a conspicuous landmark against the sky and destined to endure for all time.

The modern student of geology may smile at some of the speculations contained in the earlier proceedings, founded on the supposed persistency of lithological characters in the several formations,—as though the streams the world over were charged with the same sediments; as though the ocean floor everywhere contained the same forms of organic life; and as though volcanoes were simultaneously excited and poured forth the same igneous products; but to their honor be it said that that little band of men, who, unheralded and without parade, thus assembled at Philadelphia, in 1840, were emphatically the fathers of American geology.

Of the original founders time has more than decimated their ranks. Of the survivors some are in this presence and will participate in these proceedings. But I must not speak of the living, however meritorious; my reminiscences are of the dead. And in this connection I would recall the name of Bailey, who, armed with the microscope, brought out results in the organic world almost as wonderful as those of Ehrenberg; of Mather and Vanuxem, and Ducatel, and Locke, who, to patient industry united keen powers of observation, and who have left behind enduring memorials; of Henry D. Rogers, who made some of the grandest generalizations in American geology and whose merits were recognized in both hemispheres; of Houghton, who devised an admirable system of geological survey in connection with the lineal survey of the public domain, and from whom I parted a few hours before he became engulphed in the remorseless waves of Lake Superior;

of Niccolet, a foreigner by birth, impoverished in means, and in feeble health, who, after five years' toil brought out his astronomical survey of the valley of the Upper Mississippi; of Redfield, among the foremost of our observers in meteorology; of A. A. Gould, eminent as a conchologist, and an ardent promoter of all science, who was stricken down by the cholera when returning, after the war, from a meeting of this Association, at which he helped to revive its drooping fortunes; of Johnson, whose report on the comparative evaporative power of our coals may yet be consulted with advantage; of R. C. Taylor, whose work on "The Statistics of Coal" contains a vast range of information which has served as the basis of our subsequent investigation; of Harlan, who, at that time, was our only comparative anatomist; of Morton, among the most brilliant of our scientific men, who died prematurely for his own fame, prematurely for the cause of science; and last but not least, of Hitchcock, the veteran observer, and Silliman, who in his Journal, combined and crystallized American science. Hitchcock and Silliman went down to the grave ripe in years and crowned with honors; and when I see before me the sons engaged in the same pursuits which the fathers illustrated and adorned, I am reminded that

> "E'en in their ashes live their wonted fires."

I have deemed it proper on this occasion to pay this passing tribute to the memory of these early cultivators of American science. I fear, gentlemen, that I have detained you too long. Again thanking you for your courtesy, I close with the expression of the hope that our deliberations may be harmonious, and that they may tend, in the language which we have incorporated into our title, to "the Advancement of Science."

At the close of the address the Association proceeded to business, and elected Mr. F. W. Putnam, Permanent Secretary *pro tem.* in the absence, in Europe, of Prof. Lovering. Six additional members of the Standing Committee were elected by ballot, according to the requirement of Rule 4 of the Constition. The names of those chosen are printed elsewhere with the names of the other members of that committee.

Later in the session the Association voted to hold its next meeting at Troy, N. Y., beginning on Wednesday, August 3, 1870. The officers elected for the next meeting are:—

Prof. WILLIAM CHAUVENET, of St. Louis, *President;* T. S. HUNT, Esq., of Montreal, *Vice-President;* Prof. C. F. HARTT, of Ithaca, *General Secretary;* Dr. A. L. ELWYN, of Philadelphia, *Treasurer.* Prof. JOSEPH LOVERING was elected *Permanent Secretary* for another term of two years commencing with the Troy Meeting.

On the afternoon of Wednesday, August 18, the members of the Association were present, by invitation, at the dedication of the Peabody Academy of Science. On Friday evening, August 20, the address of Dr. B. A. Gould, the retiring President, was given in the Tabernacle Church. There was a general session at Lyceum Hall on Thursday evening, to witness some physiological experiments by Dr. J. B. Upham and others.

Many of the members in attendance upon this meeting accepted the private hospitality, generously offered by families in the city of Salem. On Saturday, August 21, by invitation of the City Council of Salem, the American Association for the Advancement of Science enjoyed an excursion in the bay on board the steamer Escort, which was gaily decorated for the occasion. The boat, with a company of between four and five hundred ladies and gentlemen on board, proceeded to Minot's Light and afterwards to Fort Warren. Major McConnell, the officer of the day, received the excursionists, who, headed by Mayors Cogswell of Salem and Shurtleff of Boston, entered the fortress gate, marching to the music of the accompanying band. After spending a short time in viewing the various objects of interest in and about the fort, they reëmbarked and proceeded to Nahant; where a dinner, provided by the city authorities of Salem, was eaten in the Maolis Garden. At four o'clock the steamer was again taken and, after a very pleasant sail along the Gloucester, Manchester, and Beverly shores, the party returned to Salem.

On different evenings of the session, receptions were given by W. C. Endicott, Esq., Mrs. Walcott, Dr. G. B. Loring, and the Salem Board of Trade.

RESOLUTIONS ADOPTED.

Resolved, That a committee be appointed to act as the correspondents of the various local committees, and assist them in making arrangements with the different railroads throughout the country for the transportation of the members of the Association to and from the meeting.

Resolved, That a request be addressed by the President of the Association to the Secretary of State of the United States, asking for the influence of the State Department, with the civil authorities of Paraguay, to procure the restoration of the manuscripts of Mr. Porter C. Bliss, relating to the Indian languages of South American, of which he was deprived by order of President Lopez, and which are now supposed to be in his custody.

The following resolution from the Subsection of Archæology and Ethnology was approved by the Association.

Resolved. 1. As the sense of the Subsection of Archæology and Ethnology that explorations for the collection of remains of Aboriginal Art are essential to progress, and that the Section takes this method and occasion to express their interest in, and commendation of, the proposed expedition of Mr. McNiel to Nicaragua. 2. That a copy of this resolution be presented to Mr. McNiel.

Resolutions relating to an International Statistical Congress.

Whereas This Association has been informed that a suggestion has been made on the part of some of the foreign members of the International Statistical Congress in favor of holding one of its sessions in the United States: —

Resolved, That the members of this Association hereby express their cordial approval of this suggestion, and their desire that the International Statistical Congress may decide to make the United States its place of meeting at an early day.

Resolved, That an attested copy of these resolutions be forwarded to the presiding officer of the International Statistical Congress, soon to be held at the Hague, in the Netherlands, and to the delegate representing the United States in said Congress.

Resolution in regard to the sale of Proceedings.

Resolved, That the proceeds of all future sales of Proceedings of the Association be reserved and invested by the Treasurer, to form, together with any donations for the purpose, the nucleus of a special fund, the interest of which may, at some future time, be devoted to scientific researches under the direction of the Association.

VOTES OF THANKS.

Resolved, That the thanks of this Association be tendered to the Commissioners of Essex County for the use of their admirably arranged rooms in the Old and New Court Houses in Salem.

Resolved, That the thanks of this Association are due to the Local Committee, who, by their assiduity in providing for our reception and accommodation, have rendered this session one of unusual enjoyment and long to be remembered.

Resolved, That the hearty thanks of this Association be presented to the citizens of Salem, who have so kindly and hospitably entertained the members, during the present Session.

Resolved, That the thanks of the Association are especially due to the Essex Institute, to the Trustees of the Peabody Academy of Sciences, and to the Board of Trade of the City of Salem, for their untiring exertions in providing for the accommodation of the meetings of the Association and facilitating the transaction of its business.

Resolved, That the thanks of the Association are due, and are most respectfully offered, to the ladies of Salem, who have so kindly and hospitably taken charge of the refreshment tables, which have been daily spread for our welfare.

Resolved, That the thanks of the Association be tendered to the Proprietors of the Tabernacle Church, for the use of their church and vestry during the present session.

Resolved, That the sincere thanks of the Association are hereby tendered to the Athenæum of Salem, to the Museum of

Comparative Anatomy at Cambridge, to the Authorities of Boston, to the Massachusetts Institute of Technology, to the Boston Natural History Society, to the American Academy of Arts and Sciences, to the Massachusetts Horticultural Society, and to the Boston Music Hall Association, for courtesies shown to this Association, and at the same time the Association begs to express its regret that, by reason of the press of business, it was unable, in all instances, to avail itself of these courtesies.

Resolved, That the Association acknowledges its obligation to the Directors of the following railroads, and especially of the Eastern railroad, for their liberality in granting a reduction of fare to the members attending the present session.

Eastern.
Boston and Albany.
Boston and Providence.
New York, Providence, & Boston.
Boston and Maine.
Portland, Saco and Portsmouth.
Fitchburg.
Vermont and Massachusetts.
Vermont Central and Sullivan.
Connecticut and Passumpsic.
Boston, Lowell and Nashua.
Portland and Kennebec.
Richmond, Fredericksburg and Potomac.
Richmond and Petersburg.
Virginia and Tennessee Southside.
Norfolk and Petersburg.
South Carolina.
Memphis and Charleston.
North Eastern.
Illinois Central.
Great Western.
Wilmington and Manchester.
Nashville and Chattanooga.
Hartford and New Haven.
Terre Haute and Indianapolis.
Marietta and Cincinnati.
Indianapolis, Cincinnati & Lafayette.

A resolution was also passed expressing thanks to the Horse Railroad Companies of Salem for courtesies extended to the members of the Association.

A resolution was also passed expressing high appreciation and commendation by the Association of the Peabody Academy of Science in Salem.

Also a resolution, giving a vote of thanks to the Mayor and City Council of Salem, for the Excursion on Saturday, the 21st of August.

REPORT OF THE PERMANENT SECRETARY.

This report relates to those transactions of business which belong to the interval between the first day of the Chicago meeting [August 5, 1868] and the first day of the Salem meeting [August 18, 1869].

During my absence in Europe, the details of my office have received prompt attention, as heretofore. The Chicago volume has been printed under the direction of Mr. F. W. Putnam, the Director of the Peabody Academy of Science, and distributed by my assistant, Mr. J. W. Harris. Circulars were sent to those members of the Association who were indebted to it for assessments, and the collection of money, in response to these circulars, has been considerable, although many are still largely in arrears.

The financial condition of the Association is as follows: —

Between August 5, 1868, and August 18, 1869, the income of the Association was three thousand and eleven dollars and thirty cents ($3 011.30).

Of this amount, one hundred and eleven dollars accrued from the sale of the printed Proceedings, and the remainder from the admission fee and the annual assessments.

The expenses of the Association, during the same interval, amounted to nineteen hundred and fifty-one dollars and seventy-seven cents ($1951.77), which may be apportioned thus: —

Cost of paper, printing, and binding, for the volume of Chicago Proceedings, and expense of its distribution, ...	$1 243.04
Charges connected with the Chicago meeting, .	$144.35
Salary of the Permanent Secretary, five hundred dollars, ...	$500.00
Circulars, postage, stationery, express, . . .	$64.38

The particular items may be found in the cash account of the Secretary, which is herewith submitted as a part of his report. The balance in the Treasury of the Association on August 18, 1869, is twelve hundred and twenty-five dollars and nine cents ($1 225.09).

JOSEPH LOVERING,
Permanent Secretary.

SALEM, August 18, 1869.

CASH ACCOUNT OF THE

Dr. AMERICAN ASSOCIATION *in*

J. W. Harris's bill as clerk,	$60.85
Stowell's bill for copying,	2.00
Janitor at Chicago,	1.50
Postage Stamps,	9.00
Freight to the Smithsonian Institution,	3.60
Binding Cash Book,	1.00
Printing Circulars,	5.00
Box to and from Chicago,	10.79
Envelopes,	1.38
F. W. Putnam, for postage,	12.21
Guests' bill for reporting,	5.00
Adams' bill for binding Proceedings,	84.78
Postage stamps,	16.00
Carter, for paper and envelopes,	3.00
Ripley, for printing circulars,	6.00
Salary of the Permanent Secretary,	500.00
Paper and printing for the Chicago Proceedings,	1,153.21
Box of Proceedings to Washington,	1.45
Attendance at the Chicago meeting,	75.00
	1,951.77
Balance to next account,	1,225.09
	3,176.86

PERMANENT SECRETARY. Cr.

Account with JOSEPH LOVERING.

Balance from last account,*	$165.56
Assessments (from No. 1 to No. 451 of Cash Books) including the sale of Proceedings, . . .	3,011.30
	3,176.86

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* This was erroneously printed, in the last volume, as $159.56.

STOCK ACCOUNT OF THE PERMANENT SECRETARY.

Volumes Distributed or Sold, since the report in Vol. XVI.

VOLUMES.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.
Distributed to Members,	1	1	1	2	2			1		1	3	2	7	19	64	226	358
Harvard College,																1	1
Yale College,																1	1
Boston American Academy,																1	1
Boston Nat. Hist. Society,																1	1
Boston Athenæum,																1	1
Boston City Library,																1	1
Conn. Acad. Sciences,																1	1
Brown University,														1	1	1	1
Smithsonian Institution,														1	1	1	1
Providence Athenæum,														1	1	1	1
Foreign Societies,*																58	58
Sold,	6	3	3	7	1	7	1		1		1	2	2	4	5	61	18
Total,	7	4	4	9	3	7	1	1	1	1	4	4	9	26	72	355	444
Balance, April, 1868,	48	99	234	224	420	283	515	837	987	876	815	935	1000	1139	644	813	942
Received from Binders,																	
Balance, May, 1870,	41	95	230	215	417	276	514	836	986	875	811	931	991	1113	572	458	498

*See pages 301 and 302.

List of European Institutions to which Copies of Volume XVII. of the Proceedings of the American Association were distributed by the Permanent Secretary in 1869.

Stockholm,—Kongliga Svenska Vetenskaps Akademien.
Copenhagen,—Kongel. danske Vidensk. Selskab.
Moscow,—Société Impériale des Naturalistes.
St. Petersburg,—Académie Impériale des Sciences.
" " Kais. Russ. Mineralogische Gesellschaft.
" " Observatoire Physique Centrale de Russie.
Pulkowa,—Observatoire Imperiale.
Amsterdam,—Académie Royale des Sciences.
" Genootschap Natura Artis Magistra.
" Zoological Garden.
Haarlem,—Hollandsche Maatschappij der Wettenschappen.
Leyden,—Musée d'Histoire Naturelle.
Altenburg,—Naturforschende Gesellschaft.
Berlin,—K. P. Akademie der Wissenschaften.
" Gesellschaft für Erdkunde.
Bonn,—Naturhist. Verein der Preussisch. Rheinlandes, &c.
Breslau,—K. L. C. Akademie der Naturforscher.
Dresden,—K. L. C. Deutsche Akademie der Naturforscher.
Franckfurt,—Senckenbergische Naturforschende Gesellschaft.
Freiburg,—Königlich-Sächsische Bergakademie.
Göttingen,—Königl. Gesellschaft der Wissenschaften.
Hamburg,—Naturwissenschaftlicher Verein.
Hannover,—Die Naturhistorische Gesellschaft.
Leipsic,—Königlich Sächsische Gesellschaft der Wissenschaften.
Munich,—K. B. Akademie der Wissenschaften.
Prag,—K. Böhm. Gesellschaft der Wissenschaften.
Stuttgart,—Verein für Vaterländische Naturkunde.
Vienna,—K. Akademie der Wissenschaften.
" K. K. Geographischen Gesellschaft.
" Geologischen Reichsanstalt.
Württemburg,—Der Verein für Vaterländische Naturkunde.
Basel,—Naturforschende Gesellschaft.
Bern,—Allgemeine Schweizerische Gesellschaft.
" Naturforschende Gesellschaft.

Genève,—Société de Physique et d'Histoire Naturelle.
Neuchatel,—Société des Sciences Naturelles.
Bruxelles,—Académie Royale des Sciences, &c.
Cherbourg,—Société Académique.
Dijon,—Académie des Sciences, &c.
Liège,—Société Royale des Sciences.
Lille,—Société Nationale des Sciences, de l'Agriculture, et des Arts.
Montpellier,—Académie des Sciences et Lettres.*
Paris,—Institut de France.
  " Société Philomatique.
  " Société Météorologique de France.
Turin,—Accademia Reale delle Scienzie.
Madrid,—Real Academia de Ciencias.
Cambridge,—Cambridge Philosophical Society.
Dublin,—Royal Irish Academy.
Edinburgh,—Royal Society.
London,—Board of Admiralty.
  " East India Company.
  " Museum of Practical Geology.
  " Royal Society.
  " Royal Astronomical Society.
  " Royal Geographical Society.
Manchester,—Literary and Philosophical Society.
Batavia,—Societé des Arts et des Sciences.

* Also Volumes XV. and XVI.

REPORTS.

Professor John Torrey, from the committee on Weights and Measures, reported and recommended the following resolution, which was adopted:

Resolved, That this Association cordially approves the proposed adaptation of American coinage to the metric system, by making the value of the dollar precisely that of one and a half grains of fine gold: — seeing in this a new step toward the promotion of fraternity among nations, by the unification of weights, measures, and coinage, inasmuch as all monetary units which have simple relations to the grains must have simple relations to each other.

Prof. L. Agassiz, from the committee on the Jubilæum of Ehrenberg, reported that the duties assigned to the committee were completed. The report was accepted and the committee discharged.

Dr. B. A. Gould, from the committee on the star *Eta Argus*, reported that the duties assigned to this committee were completed, and the committee was discharged.

REPORT ON THE MICROSCOPES AND MICROSCOPICAL APPARATUS, EXHIBITED AT THE MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AT SALEM, MASS., AUGUST, 1869.

THE local committee having determined to provide suitable rooms for an exhibition of Microscopes at the Salem meeting of the American Association for the Advancement of Science, a sub-committee was appointed to take charge of the exhibition. The committee having organized by the choice of Mr. James Kimball for chairman, and Mr. Edwin Bicknell as secretary, it was voted, "That the secretary prepare a suitable circular to be sent to all microscopists and others interested in the use of the microscope;" and in obedience to the vote of the sub-committee, the following circular was prepared.

A. A. A. S.

Special Circular to Persons Interested in the Use of the Microscope.—In making arrangements for the meeting of the American Association for the Advancement of Science, to be held at Salem, commencing at 10 A. M., August 18th, 1869, the Local Committee, in order to give encouragement to the general and increasing interest in the use of the Microscope, have decided to furnish rooms for the display and comparison of Microscopes, Objectives, Accessory Apparatus of all kinds, Test Objects, and Objects of Scientific and Popular interest.

It is intended to have as complete a collection as possible of instruments of both American and Foreign Manufacture. Those who are possessed of Microscope stands, Objectives, or Accessory Apparatus in any way remarkable for excellence of performance or design, are requested to bring them to the meeting.

The objects of this exhibition will be to assist the progress of scientific research, by social intercourse and a full comparison and discussion of whatever is new and important in microscopical investigation, and to encourage the manufacture and use of this valuable instrument.

Arrangements have been made to give ample opportunity for the use of the Microscopes both day and evening. A safe place has been secured for the deposit of instruments sent beforehand to the care of Mr. Bicknell, or brought by visitors who do not wish to keep them in their own possession.

A sub-committee has been appointed by the local committee to make the necessary arrangements. Farther information relating to the subject can be had by addressing

EDWIN BICKNELL,
Sec'y of the Sub-committee,
PEABODY ACADEMY OF SCIENCE.
SALEM, MASS.

SALEM, May 29, 1869.

This circular was sent, with the circular of the local committee, to the members of the Association, and to all others interested in the use of the microscope, as far as we were able to ascertain their addresses.

The distribution of this circular resulted in a gathering of twenty-five or more microscopes of different classes, including four quite old, and interesting on that account, and two not quite as old, the rest being of modern construction. Before giving a description of the modern microscopes, I shall briefly describe the old ones, and would here state that the old microscopes were shown in comparison with the modern ones in order to give the beholder a nearly correct idea of the improvements which have been made from time to time in the construction of microscopes, and to show the wonderful progress which has been made, particularly in objectives.

The oldest microscope is after the pattern described in 1694, by Hartsoeker, a Dutchman, but there is no certainty that this one was made by him. It is about two and a half inches long, and is held up to the eye to view the object, and has a condensing lens in the end opposite the eye. The object is placed between the eye lens and the condensing lens, by which it is adapted only for transparent objects. It is provided with six eye-glasses.

The next is a microscope made by G. F. Brander, in Augsburg, Germany, and is described in 1769. It is on a stand, by which it can be used either vertically, inclined, or in a horizontal position; it can be used as a simple or compound microscope, and with transparent or opaque objects. It has eight object-glasses, two of them provided with Lieberkuhns, and has a compound body, which, being removed, converts it into a simple microscope, similar to the one first described. It has a Ramsden's eye-piece mounted in wood.

The above mentioned microscopes belong to Dr. William Wood of Portland, Maine.

The next is a Lieuwenhoek microscope made by G. Adams of London, about 1750, bought by D. Van der Weyde, A. M., in Amsterdam, in 1763. It is now owned by P. H. Van der Weyde of New York. In this microscope there are six eye-glasses set in a revolving plate, so that each eye-glass can be brought in succession over the object, thus saving the trouble of unscrewing.

The next is a compound microscope, made by Charles Lincoln, 62 Leadenhall street, London, in 1770, and is owned by Dr. G. A. Perkins, of Salem. This is vertical, and stands on three scrolls and has eight object glasses with one eye-piece of the Ramsden pattern.

This concludes the notice of the old instruments.

The remaining instruments were of modern construction.

The next is by Clarke of London, is owned by the Essex Institute, Salem, was made about 1830, and was a complete instrument in its day.

The next is Andrew Pritchard's large microscope, made about 1840, also owned by the Essex Institute, and was the best of its period, having a full set of objectives and accessories.

Prof. Edward W. Morley of the Western Reserve College, exhibited a large and beautiful stand made by Thomas Ross. This has three eye-pieces, a Troughton & Sims' cobweb micrometer and goniometer, and other accessories.

Dr. D. H. Briggs of Norton, Mass., exhibited a first class Smith & Beck binocular with a complete series of objectives and accessory apparatus.

Benjamin Webb, Jr., of Salem, Mass., exhibited a first class Smith & Beck binocular with a complete outfit of objectives from three inch to one-fifteenth, by Smith & Beck, Spencer, and Wales; also a complete set of accessory apparatus.

Prof. J. Baker Edwards of Montreal, Canada, exhibited a first class binocular made by Pillischer of London, with a complete outfit of accessory apparatus and objectives by Smith & Beck and Andrew Ross. Prof. Edwards also exhibited a Sorby & Browning micro-spectroscope.

Dr. R. H. Ward of Troy, New York, exhibited a first class binocular by Crouch of London, with "Collins' graduating diaphragm," and "Crouch's universal parabolic illuminator."

Prof. B. Silliman of New Haven, exhibited a first class microscope by J. Grunow of New York, with goniometer eyepiece and objectives by Grunow, Wales, and Tolles.

Dr. P. H. Van der Weyde of New York city, exhibited a microscope made by Andrew Ross, which had a very ingenious arrangement of his own for converting it into an inverted microscope for chemical use.

Mr. Charles Stodder of Boston, Mass., exhibited a first class microscope made by the Boston Optical Works, which was a very fine instrument. It had a very thin stage which revolved on the optical centre of the instrument, making it very useful for certain purposes.

Mr. Alpheus Hyatt of Salem, Mass., exhibited a first class microscope made by Joseph Zentmayer of Philadelphia. With this was exhibited a full assortment of accessory apparatus of Mr. Zentmayer's make.

Mr. Edwin Bicknell also exhibited a first class microscope by Zentmayer, objectives by Tolles and Wales. Tolles' solid *D.* and *E.* eye-pieces, Tolles' amplifier, and one-fourth inch objective with Tolles' new illuminator for opaque objects.

A very large, and in its time complete microscope, made by Chevalier of Paris, was exhibited by Mr. Chamberlain of Boston, Mass. In addition to the objectives furnished by Chevalier, it had objectives by Andrew Ross, and Andrew Pritchard.

Mr. E. Bicknell exhibited a Zentmayer's "Army Hospital Microscope." This is admirably adapted to the use of the physician and student.

Mr. Charles Stodder exhibited four student's microscopes from the Boston Optical Works, the stands of the same pattern, but with different kinds of adjustment for focus, and different stage arrangements. Mr. Stodder also exhibited the new "Clinical" and "Seaside" microscope, of the pattern recommended by Dr. Cutter of Boston. This can be transformed into a fine pocket telescope by having a suitable object-glass adapted to it.

Prof. A. M. Edwards of New York, exhibited a student's microscope made by F. Miller & Brother of New York. This has one eye-piece and a dividing objective, thus giving two powers, and is furnished at a low cost.

Mr. F. G. Sanborn of Boston, exhibited a Murray & Heath sea-side microscope, which was a very neat instrument.

Mr. C. G. Bush of Boston, exhibited a Smith & Beck students microscope, with Smith & Beck's and Tolles' objectives.

Mr. A. H. Tuttle of Platteville, Wisconsin, exhibited a neat stand for a "dissecting microscope," in which the stand and arm-rests are made to fold into a very small compass.

Several immerson objectives were exhibited, including a $\frac{1}{15}$, $\frac{1}{10}$, $\frac{1}{6}$, $\frac{1}{4}$, by Tolles, two $\frac{1}{15}$ by Wales, and No. 10 and No. 12 by Hartnack of Paris. Mr. Tolles has recently constructed some immersion objectives for the use of the physician, for the examination of blood, pus, sputum, urinary deposits, &c. In these objectives the substance to be examined is placed upon the front lens of the objective and covered with a piece of thin glass, which is kept in place by capillary attraction. The focus is obtained by the use of the "cover adjustment." This objective applied to the "clinical microscope," before described, is a very useful instrument for the medical practitioner.

Mr. Tolles has also recently made several objectives of long focal distance on the immersion principle, which are admirably adapted to viewing objects in aquaria, or for dissecting under water. One shown by Mr. Bicknell had a power equal to an ordinary objective of ¾ inch focal distance, and with a working distance of an inch. This objective showed well the circulation of cell contents in the Nitella.

Two objectives made by Mr. Tolles of $\frac{4}{10}$ and ¼ inch respectively, were provided with his "illuminator for opaque objects," which is a glass prism set in the mounting of the objective between the front and middle combinations, so that the light is thrown down through the front lens upon the object, and so far as tested they have worked very well indeed, showing the object without glare or fog and with plenty of illumination; the ¼ being constructed upon the immersion principle, could be used upon a covered object with perfect results.

Mr. E. Bicknell exhibited a very neat apparatus for cutting sections of wood, &c.; also a new graduating diaphragm, both made by Mr. Zentmayer of Philadelphia.

EDWIN BICKNELL,
Secretary of Sub-section of Microscopy.

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